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THE LINEAR HOT-WIRE ANEMOMETER AND ITS APPLICATIONS IN TECHNICAL PHYSICS.*

BY

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In the spring and summer of 1912 the writer commenced a series of experiments [1] on the laws of cooling of electrically-heated wires in a stream of air with a view to applying this principle to the accurate measurement of air-velocity.[2] As there is always a great advantage to be gained by being able to plan apparatus, take observations, and discuss experimental results in conformity with a mathematical investigation of the subject, the theoretical problem of calculating the rate of loss of heat from a cylinder immersed

* Communicated by the Author.

[1] An account of these experiments was read before the Royal Society of Canada, May 28, 1913. A full account of the subject, the development of which is briefly sketched in the present article, will be found in a series of papers by the writer: (i) King, L. V., "On the Convection of Heat from Small Cylinders in a Stream of Fluid: Determination of the Convection Constants of Small Platinum Wires, with Applications to Hot-wire Anemometry," *Phil. Trans. Roy. Soc. London,* vol. 214 A, 1914, pp. 373–432; abstract in the *Proc. Roy. Soc. London,* vol. 90A, 1914, pp. 563–670. (ii) *Phil. Mag.,* vol. 29, April, 1915, pp. 556–577. (iii) *British Patent Specification,* No. 18,563, 1914.

[2] It is interesting to note that researches with this idea in view were undertaken almost simultaneously by investigators in England, Italy, Germany, the United States and Canada. Preliminary experiments on the use

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in a stream of fluid flowing at right angles to the length of the cylinder was first discussed in some detail. In the form derived by Poisson and Ostrogradsky the general differential equations for the conduction of heat in a moving medium are intractable. In the particular problem under consideration, the cylinder is supposed to be immersed in a perfect, thermally-conducting fluid, so that the flow around it gives rise to a system of hydrodynamical stream-lines and equipotentials which intersect everywhere at right angles and define a system of orthogonal coördinates. It was discovered by Boussinesq,[3] in 1905, that by referring the conduction of heat to this system of curves instead of to a system of (x, y) coördinates, the equation of heat-conduction when thus transformed is much simplified and takes a form whose solution is comparatively simple. Further progress to a final result requires some assumption to be made as to the conditions of heat-flow at the boundary of the heated cylinder and the fluid flowing past it. On this subject we have, unfortunately, almost no direct physical evidence: Boussinesq assumes, for the purpose of calculation, that the fluid which *slips* past the cylinder is at the separating boundary

of a platinum wire heated by an electric current for the measurement of wind-velocity were carried out by G. A. Shakespear, at Birmingham, as early as 1902, but were discontinued for lack of facilities in the erection of a suitable whirling table for the calibration of the wires. Electrical anemometry was independently suggested by A. E. Kennelly in 1909 (A. E. Kennelly, C. A. Wright, and J. S. Van Blyevelt, *Trans. A. I. E. E.*, 28, pp. 363–397, June, 1909), and, although the actual application to anemometry appears to have been made as early as 1911, the results have only recently been published (A. E. Kennelly and H. S. Sanborn, *Proc. of the American Phil. Soc.*, **8**, pp. 55–77, April 24, 1914). Electrical anemometry was also developed independently by U. Bordoni (paper read before the Societé Italiana per il Progresso delle Scienze, October 18, 1911; published in the *Nuovo Cimento*, series 6, vol. iii, pp. 241–283, April, 1912; see also *Electrician*, 70, p. 278, November 22, 1912), and by J. T. Morris (paper read at the British Association, Dundee, September 27, 1912; published in the *Engineer*, September 27, 1912; the *Electrician*, October 4, 1912, p. 1056, and November 22, 1912, p. 278), *British Patent Specification*, No. 25,923, 1913. A form of integrating hot-wire anemometer has also been described by H. Gerdien (*Ber. der deutschen phys. Ges.*, heft 20, 1913). The use of a hot-wire anemometer in the measurement of non-turbulent air currents is described by C. Retschy in a series of short papers published in *Der Motorwagen*, vol. 15, March–July, 1912.

[3] Boussinesq, *Comptes Rendus*, vol. 133, p. 257; also *Journal de Mathématiques*, vol. i, pp. 285–332, 1905.

at the same temperature as that of the surface of the solid; he then neglects an entire term of the differential equation representing the conduction of heat away from the cylinder in the case where the velocity of the stream is zero, and finally obtained for the rate of loss of heat H from unit length of cylinder of radius a immersed in a fluid of small thermal conductivity κ, density σ, and specific heat s per unit mass the formula

$$H = 8\sqrt{(s\sigma\kappa Va/\pi)}\theta_0 \quad \text{(1)}$$

where θ_0 is the excess of temperature of the cylinder above that of the fluid at a distance. This is known as Boussinesq's Formula and is quoted in several recent papers on the convection of heat.

It was found that the formula (1) did not agree with the results of experiment in the heat loss from small wires: the writer, therefore, undertook the rigorous solution of the differential equations of heat-flow from a cylinder in a stream of fluid in such a way that any boundary condition might be employed at will. Unfortunately, our knowledge of the physical conditions determining the transfer of heat across the boundary separating a solid from a liquid or a gas are still very imperfect. The result in best agreement with observation on heat losses in air was obtained from the assumption of a boundary-condition of constant flux; that is, that the rate of transfer of heat from the solid to the gas is constant over the boundary and independent of the velocity of slip past the solid.

In these conditions, the heat loss per unit length from a cylinder of radius a is given by the equation

$$4\pi s\sigma Va/[\int_0^{4a} e^u K_0(u)du] \quad \text{(2)}$$

where $K_0(u)$ is that solution of Bessel's equation most conveniently defined by the definite integral

$$K_0(u) = \int_0^\infty e^{-u\cosh\phi}d\phi \quad \text{(3)}$$

In order to test the theory, it is necessary to tabulate the function $\int_0^x e^u K_0(u)du$. Use is made of the tabulated values of the function $K_0(x)$, and the integral is evaluated step by step by making use of Euler's formula for quadratures, the arithmetical operations being easily carried out by means of a calculating machine. The graph of the function $y = x / [\int_0^x e^u K_0(u)du]$ plotted

against $\sqrt{x}$ is shown in Fig. 1. Over the range of values of the variable corresponding to the interpretation of the experiments on the convection of heat the curve lies extremely close to its asymptote

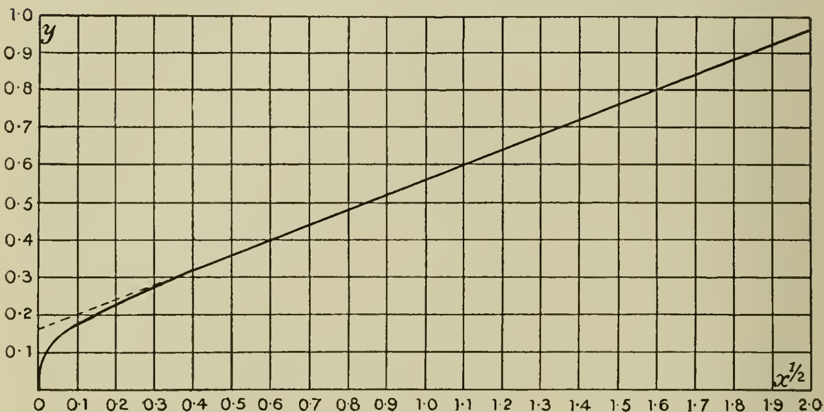
$$y = 1/(2\pi) + \sqrt{[x/(2\pi)]} \qquad (4)$$

while for small values of the variable it can easily be shown that an approximate value is given by

$$y = 1/[(1 - \gamma) - \log \tfrac{1}{2}x] \qquad (5)$$

γ being Euler's constant, $\gamma = 0.5771$. The corresponding expres-

FIG. 1.



Graph of the function $x \Big/ \left[\int^x e^x K_0(x)dx.\right]$.

sions for the heat-loss per unit length for a cylindrical wire of radius a are:

$$\text{(High velocities)}\ H = \kappa\theta_0 + 2\sqrt{(\pi\kappa s\sigma a)}\,V^{\frac{1}{2}}\theta_0 \qquad (6)$$

$$\text{(Low velocities)}\ H = 2\pi\kappa\theta_0/(\log b/a) \qquad (7)$$

where b in (7) is given by $b = \kappa e^{1-\gamma}/(s\sigma V)$.

The boundary condition of constant flux gives rise to a discontinuity of temperature over the boundary. From the point of view of the kinetic theory of gases, temperature conditions can not be strictly defined in the immediate neighborhood of the heated cylinder, and it is only at a distance of several free paths, when equi-partition of molecular energies is nearly complete, that temperature can strictly be defined and that normal thermal conduction takes place.

It may be argued that the application of the preceding theory to reality is somewhat remote in view of the fact that viscosity has not been taken into account in the preceding analysis. There are many difficulties in the more complete treatment of the problem: not only do the equations for heat-flow become very much more complicated when viscosity is included in the hydrodynamic equations, but it must be remembered that such solutions for stream-line flow as have been obtained for flow of velocity V past a circular cylinder of radius a apply only to values of the fraction Va/ν small compared to unity, ν being the kinematic coefficient of viscosity. ($\nu = \mu\sigma$ where μ is the coefficient of viscosity and σ the density of the fluid: for water at 0° C., $\nu = .0178$ and for air $\nu = .132$). This condition fails to hold over almost the entire range of velocities met with in practice, even in dealing with wires as fine as 1 mil (1/1000 inch) in diameter. It may also be pointed out that nothing is known as to conditions under which stream-line motion gives place to turbulent flow in the case of cylinders as small as the wires employed by the writer in hot-wire anemometry (1 to 6 mils in diameter). In the experiments described below on the determination of convection constants of small platinum wires the writer fully expected to find points of discontinuous behavior on increasing the velocity of the air past the wire; in all these experiments the curves were quite smooth to velocities as high as 30 metres/second. It is thus probable that in the case of these very small cylinders the motion is stream-line throughout, and at the comparatively high velocities employed it is not impossible that the distribution of stream-lines may not differ very much from that in a perfect fluid except in a region in the immediate neighborhood of the cylinder. In these circumstances it is probable that the effect of viscosity is chiefly felt in this comparatively thin "skin," and that the experimental boundary condition of constant flux is an effect of thermal conduction in the "transition layer" under the conditions mentioned.

This point of view receives some support from a powerful treatment of the problem by Lord Rayleigh, based on the principle of similitude.[4] By an application of the theory of dimen-

[4] Rayleigh, "The Principle of Similitude," *Nature*, 95, March 18, 1915, pp. 66–68. The notation is slightly changed to conform to that employed in the present paper. For a further discussion see Riabouchinsky, D., *Nature*, 95, July 29, 1915, p. 591. Also Larmor, *Nature*, 95, August 12, 1915, p. 644.

sions described in his paper it is shown that, taking into account viscosity, the expression for the heat-loss H per unit length should take the form

$$H = \kappa\theta_0 F(aVc/\kappa,\ c\nu/\kappa) \qquad (8)$$

the notation employed being the same as in (1), except that c in the present case refers to the specific heat of the fluid per unit volume. F is an arbitrary function of the two variables aVc/κ and $c/\nu\kappa$. In the paper just quoted Lord Rayleigh comes to the following conclusions: "The latter of these ($c\nu/\kappa$), being the ratio of the two diffusivities (for momentum and for temperature), is of no dimensions: it appears to be constant for a given kind of gas, and to vary only moderately from one gas to another. If we may assume the accuracy and universality of this law, $c\nu/\kappa$ is a merely numerical constant, the same for all gases, and may be omitted, so that H reduces to the forms already given[5] when viscosity is neglected altogether, F being again a function of a single variable aVc/κ. . . ."

A little consideration will show that the more general formula (2), and the approximate expressions (6) and (7) obtained by the writer, may, from this point of view, be included as a particular case of the general functional expression (8). From the physical point of view it is evident that little can be done towards the final solution of the problem until further *experimental* evidence comes to hand regarding the precise boundary conditions which exist at the interface of highly-heated metals and gases both at rest and in relative motion.

THE DETERMINATION OF THE CONVECTION CONSTANTS OF SMALL PLATINUM WIRES.

The experimental investigation briefly reviewed in the following pages was undertaken with two purposes in view:

1. To study the laws of the convection of heat from small platinum wires heated by an electric current over as wide as possible a range of temperature, air-velocity, and diameter in the light of the theoretical development outlined above, and to obtain in absolute measure the convection constants of small platinum wires.

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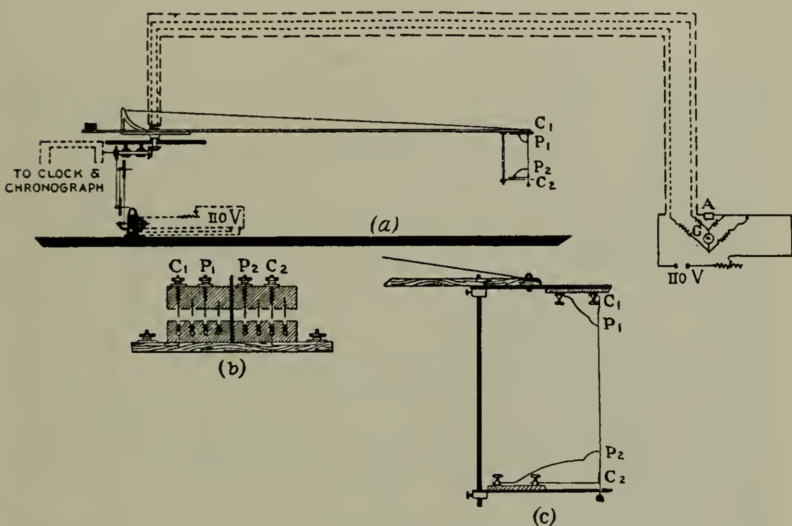
[5] Referring to formulæ of the Boussinesq type obtained for the convection of heat from bodies of various shapes immersed in a stream of fluid.

2. To make use of the constants thus obtained in the design of accurate and portable wind-measuring apparatus to form the basis of a standard system of anemometry, as well as to serve for use in a great variety of engineering and aërotechnical problems.

The general arrangement of apparatus necessary to carry out the requisite measurements of heat-losses from a series of platinum wires of diameters 1 to 6 mils is shown in Fig. 2, and con-

FIG. 2.



Rotating arm and diagrams of connections employed in the determination of the convection constants of small platinum wires.

sisted of a rotating arm capable of adjustment to any speed as calculated from a chronograph record. At various lengths along this arm could be clamped a light fork (Fig. 2 *c*) designed to hold the specimens of wire under test. The latter formed part of a Kelvin double bridge, electrical connection being obtained through a central mercury connecting switch (Fig. 2 *b*) and overhead wires to the remainder of the bridge. By means of a rheostat it was possible at each speed to adjust a measured current through the wire so as to bring its resistance to a value corresponding to a predetermined temperature. In this way it was possible to vary at will the various factors of temperature, air-velocity, and heat-loss.

In order to obtain a correct measurement of velocity by the use of a rotating arm, it was found necessary to make a correction for the velocity of the vortex set up in the laboratory. This was accomplished by making use of one of the wires previously tested on the rotating arm as a hot-wire anemometer for measuring the velocity of the vortex set up by the whirling table. For a wire fixed at any radius it was found that the velocity V relative to the air of the room is connected with the velocity V_r relative to the room itself by the relation $V=(1-s)V_r$, s being a constant for the radius employed and the disposition of the apparatus in the room. The constant s may be conveniently called the "swirl" and expressed in percentages of the apparent velocity: for a radius of 2.6 metres s is as much as 5 per cent.

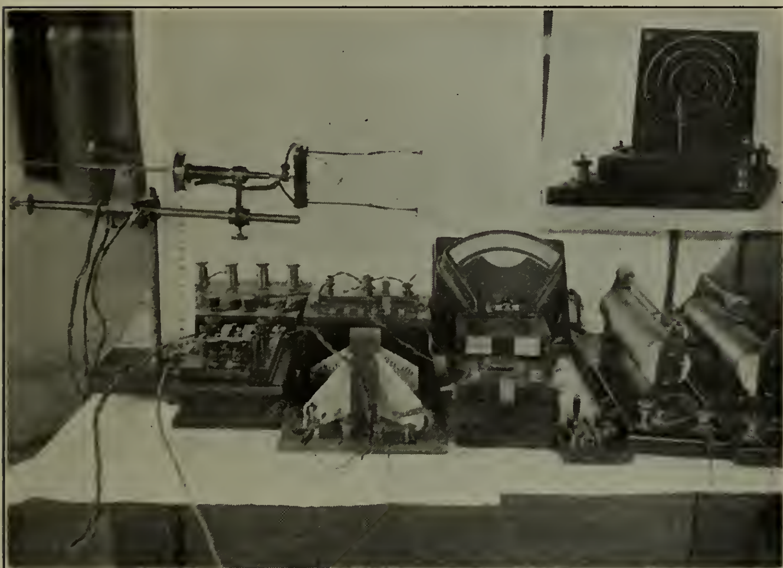
The wires employed were drawn down through diamond dies from a length of 6-mil pure platinum wire whose constants were accurately known for the purposes of platinum thermometry. It was found necessary to redetermine the temperature coefficients after each wire had been heated for a considerable time to about 1200° C. in the course of the convection experiments. The diameters of the 10 sizes of wire tested (from 6 to 1 mil) were directly measured to within 1 per cent. by means of a high-power microscope.

Under conditions of rapid cooling by convection, the calculation of the temperatures of the wire from its resistance may be subject to uncertainties, due to the existence of gradients of temperature. It was shown by calculation that under extreme conditions the excess of temperature of the centre of the wire over that of the boundary can not exceed 0.6° C. at 1000° C., so that this source of error is negligible. More serious is the cooling effect of the leads and potential terminals, which must be so arranged that this source of error may be within the limits of experimental errors. The effect was calculated out in detail and a numerical table was drawn up showing that with the disposition of apparatus of the convection measurements the error due to the leads and potential terminals could be neglected. The possibility of error becomes more serious in the design of hot-wire anemometers with short wires, and in any particular case may be kept within small limits by a reference to the above-mentioned table. The importance of keeping the anemometer wire from

vibration was shown by a mathematical investigation of the error involved.

Observations on the heat-loss per unit length from a series of ten platinum wires of diameters 6 to 1 mil under varying conditions of temperature and wind-velocity were analyzed in detail. For each velocity (corrected for "swirl") the currents required to heat the wire to a predetermined series of resistances (from which the temperatures were calculated) were measured. The

PLATE I.



Portable hot-wire anemometer. The insert in the upper right-hand corner is a photographic reproduction of the mercury connecting switch shown in Fig. 2 *b*.

corresponding heat-loss W in watts per unit length was calculated for each temperature: theory suggested that the results be examined in the light of the formula $W = B\sqrt{V} + C$, where B and C are functions of the temperature and of the dimensions of the wire. When W was plotted against $\sqrt{V}$ for each temperature, a family of straight lines was obtained, and by determining the line of closest fit to the observed points the constants B and C could be found for each wire.

It was found by plotting B against $\theta - \theta_o$, the excess of tem-

perature of the wire above the surrounding air, that the resulting graph approximated very closely to a straight line for a range of temperature attaining to as high as 1200° C.: this result could be expressed by the relation $B=\beta(\theta-\theta_0)$ where β showed the existence of a small temperature coefficient represented by $\beta=\beta_0[1+b(\theta-\theta_0)]$, b having the value $b=0.00008$. Finally, theory required that β_0 be proportional to $\sqrt{a_0}$, a_0 being the radius of the wire. A graph of β_0^2 against a_0 showed this condition to be satisfied, leading to the final result

$$\beta_0/\sqrt{a_0} = 1.432 \times 10^{-3} \text{ (experimental)} \quad (9)$$

The theoretical formula (6) required

$$\beta_0/\sqrt{a_0} = 2\sqrt{(\pi s_0 \sigma_0 \kappa_0)} = 1.66 \times 10^{-3} \text{ (theoretical)} \quad (10)$$

taking $\sigma_0=0.001293$, $\kappa_0=5.66\times10^{-5}$ calorie, and $s_0=0.171$ calorie. The agreement of (9) and (10) must be considered fair in view of the uncertainty attached to the value of the thermal conductivity for air, and also in the fact that the theoretical investigation does not take into account the variation of this and other factors with the temperature gradient in the neighborhood of the wire.

In order to interpret the constant C in terms of formula (6), it was necessary to calculate the contribution of radiation to the term C. It was shown, from the observations of Lummer and Kurlbaum,[6] that the radiation loss from polished platinum at absolute temperature θ° C. is given in watts per cm.[2] by the relation

$$e = 0.514\theta/1000)^{5.2} \quad (11)$$

Having calculated the radiation loss per centimetre of the wire from the formula $E=2\pi ae$, the true convection loss $C_0=C-E$ was obtained: it was found for each wire that C_0 was very nearly proportional to the temperature difference $\theta-\theta_0$, and could be represented by the formula $C_0=\gamma_0(\theta-\theta_0)[1+c(\theta-\theta_0)]$, γ_0 being nearly independent of the diameter of the wire and having the value

$$\gamma_0 = 2.50 \times 10^{-4}(1+70a) \text{ (experimental)} \quad (12)$$

[6] More recently the accurate determination of the emissivity of pure platinum has been made the subject of a special research at the Washington Bureau of Standards: Foote, P. D., Bulletin No. 243, vol. 11, January, 1915, pp. 607–612.

According to the theoretical equation (6), $C_o = K_o(\theta - \theta_o)$, giving

$$\gamma_o = \kappa_o = 2.37 \times 10^{-4} \text{ watts (theoretical)} \qquad (13)$$

in tolerable agreement with the observed value (12). The coefficient c has the value $c=0.00114$, which may be considered to represent in large measure the variation of the heat conductivity with the temperature.

It was found that the constant β_o varied in a marked manner with the inclination of the wire to the direction of the stream, an effect which can be utilized in practical anemometry in determining the direction of the resultant flow in a complicated distribution of air-velocity.

Formula (7) for small velocities agrees in form with the empirical formula proposed by Langmuir[7] to represent the results of his experiments on the free convection of heat from small platinum wires. The corresponding mathematical problem has not yet been solved completely, but may be dealt with in the light of the present investigation by supposing that the wire is cooled by a current of effective velocity V due to the ascent of heated air over the surface of the cylinder. Making use of the constants obtained from the present experiments on forced convection, Langmuir's observations can be interpreted and the velocity of the "effective" convection current estimated: these results are of some importance in hot-wire anemometry, as the "effective" velocity sets a lower limit to the value of the air-velocities which it is possible to measure accurately by this means.

THE LINEAR HOT-WIRE ANEMOMETER.

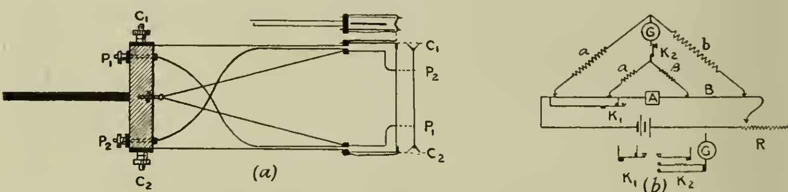
It is interesting to notice that, whereas the requirements of modern science have led to the development of means of measuring a large number of physical quantities to a high degree of accuracy, instruments for the measurement of fluid velocity have, up to within a few years, been extremely imperfect. Confining ourselves, for the moment, to the measurement of air-velocity, the first demand for a means of estimating wind-velocity arose from the needs of meteorology: it is interesting to note, in this connection, that misgivings as to the correctness of absolute

[7] Langmuir, "Conduction and Convection of Heat in Gases," *Physical Review*, vol. 34, p. 415 (1912).

determination of velocities by the well-known Robinson cup-anemometer made themselves felt many years ago, with the result that experiments carried out by Stokes[8] in 1881 and Dines[9] in 1889 led to a marked change in the constant of the instrument.

In recent years the rapid development of aëronautics and the establishment of organized aërotechnical laboratories have led to an insistent demand for an accurate and reliable means of measuring air-velocity to an accuracy of a fraction of one per cent. This need has been met by the development of the pitot-tube employed in conjunction with extremely sensitive pressure manometers. As these instruments are now extremely well known, it is unnecessary to do more than refer to the publications of any of the principal aërotechnical laboratories where specifications of the most satisfactory types of wind-measuring instruments of this kind are given in detail.[10]

FIG. 3.



Details of hot-wire anemometer and connections. (*a*) Anemometer fork. (*b*) Kelvin bridge connections.

While sufficiently accurate under most conditions, the pitot-tube suffers from grave disabilities which prohibit its use in certain circumstances where an accurate measurement of air-velocity would lead to highly interesting results. In the first place, owing to the necessity of measuring small pressure-differences and the use of a sensitive manometer controlled by gravity, the pitot-tube is not easily portable; in addition, the pressure-difference is, for velocities ordinarily met with, so small as to make it extremely difficult, if not impossible, to affect a relay

[8] Stokes, Sir. G., *Proc. Roy. Soc.*, 1881, p. 170. For the early history of the subject see Stokes, "Memoir and Scientific Correspondence," edited by Sir J. Larmor, Cambridge, 1907, pp. 230–240 and pp. 244–252.

[9] Dines, *Journ. Roy. Meteorological Society*, vol. 15, p. 1.

[10] Note in particular a paper by Rowse, W. C., "Pitot Tubes for Gas Measurement." *Journ. of the Am. Soc. of Mechanical Engineers*, 1913.

capable of operating a recording mechanism. Finally, the pitot-tube is not suitable for measuring variations of velocity close to surfaces or obstacles where the velocity-gradient is extremely high, owing to the comparatively large size of the pitot-tube orifice and the distortion of flow which it would cause under the conditions mentioned.

On the other hand, the use of anemometers based on the hot-wire principle has many advantages in dealing with special prob-

PLATE II.

Linear hot-wire anemometer showing micrometer mounting. The lower part of the figure shows a Töpler manometer for measuring minute pressure differences.

lems to be discussed in greater detail in the sequel. Several forms of instruments of this type have already been developed to a practical form.[11] The special type of instrument developed by the writer with a view to studying the complex problems relating to the stability of the flow of gases in channels and the phenomena of skin-resistance may be called a "linear anemometer" in contradistinction to several forms of integrating instruments already mentioned.

[11] See footnotes (1) and (2).

The special feature of the writer's instrument which has many advantages is the use, in conjunction with platinum anemometer wires, of the Kelvin Double Bridge shown in Fig. 3 *b;* the ratio-coils are adjusted so that $a/b = \alpha/\beta$, in which case a fundamental property of this arrangement is that when a balance is obtained on the galvanometer, $A/B = a/b = \alpha/\beta$ independently of all connecting- or contact-resistances. The resistances A and B refer respectively to the resistance of the anemometer-wire between potential terminals permanently fused to the wire and to that of a manganin resistance. The resistances a and b were made equal and about 500 ohms, while α and β were adjusted to equality at about 250 ohms. In order to protect the anemometer-wire from accidentally burning out, a key K_1 was inserted by means of which it was always short-circuited except when observations were actually being taken; a double-contact key K_2 was inserted in the galvanometer circuit in such a way that contact was first made through a high resistance in the preliminary adjustments; it was also found convenient to connect the galvanometer through an adjustable shunt. The resistance B was constructed of No. 23 B. and S. gauge manganin wire wound non-inductively on an asbestos frame so as to dissipate a maximum amount of heat; its resistance as measured between potential terminals soldered to the wire was adjusted to about four times that of the anemometer-wire at room temperature. By means of a fine-adjustment rheostat R, the current in the anemometer-wire can be adjusted until a balance is obtained in the galvanometer. It is advisable that the rheostat be always readjusted to the position of minimum current to avoid overheating the wire should the velocity of air-flow suddenly diminish; this may easily be accomplished by means of a spring control. In taking a measurement of velocity the key K_1 is pressed down and the current as read by the ammeter slowly increased until on pressing down the key K_2 a balance is obtained on the galvanometer. From the reading of the current i the velocity V may readily be obtained from a calibration curve corresponding to the formula

$$i^2 = i_0^2 + k\sqrt{V} \qquad \text{(14)}$$

or from a conversion-table connecting i and V calculated from the above expression.

The ammeter employed by the writer was a Weston direct-current instrument of range 2 ampères; the scale was equally

graduated over this range, each division representing 0.02 ampère; by estimation the current could be read to 0.002 ampère. If the conditions of air-flow are sufficiently steady and it is required to resolve small velocity differences, the use of a Weston Laboratory Standard ammeter is recommended; the scale covers a range of 1.5 ampère and is uniformly graduated directly to 0.01 ampère; by means of a diagonal scale it is possible to subdivide each division directly into fifths, and by estimation into twentieths, so that it is possible to read the current to 0.0005 ampère.

The galvanometer employed was a Weston portable instrument with jewel-bearings, of resistance 277 ohms and capable of detecting a current of about 10^{-6} ampère; this degree of sensitivity is, in fact, ten times more than is necessary. When employed in connection with hot-wire anemometry the constants of damping are very important in determining the rapidity with which observations can be made. It was found that equally sensitive galvanometers varied within wide limits in this respect.

A convenient form of fork suitable for holding in position the anemometer-wires, and offering a minimum of disturbance to the flow of air in its neighborhood, is illustrated in Fig 3 *a*. Fastened to a block of ebonite are the two arms of the fork, consisting of steel strips about 5 mm. in width. At the end of each is soldered a small brass block drilled to receive two fine needles fastened about 1 cm. apart. Threaded through the eyes is a 3-mil platinum wire having its extremities firmly clamped in the brass block just mentioned. The ends of the anemometer-wire are threaded through these two loops and secured in position by being twisted a couple of turns around the wire; the fundamental property of the Kelvin double bridge already referred to only requires the electric contact at these points to be moderately good. The tension in the wire is adjusted by a fine silk thread carried down from each of the brass blocks to an adjustable screw in the centre of the ebonite block; this thread is also effective in preventing lateral vibrations of the fork. Carried up from each end of the ebonite block are two thin steel strips crossing each other to the opposite ends of the fork, insulated from each other and also from the fork by means of thin mica strips. These steel strips, which are held in position along the arms of the fork by two lashings of fine waxed silk cord, serve to brace the fork and at the same time serve as potential leads; at each end is soldered a small brass block drilled to hold a fine needle, at the extremity

of which is soldered a short length of 6-mil platinum wire. To these are soldered one extremity of the 1-mil platinum potential terminals, the other being *fused* to the anemometer-wire; this is most easily accomplished by connecting the wire to the bridge connections and adjusting the current until it is at a bright red heat; the potential wires are then brought to the required position and wound twice around the anemometer-wire; by applying a slight tension while this is being done, a satisfactory fused contact will be effected. The free end should then be broken or cut off close to the anemometer-wire, so as to diminish the cooling effect of the potential leads. The heating to which the wire is subjected during this operation serves to anneal it sufficiently well for permanent use.

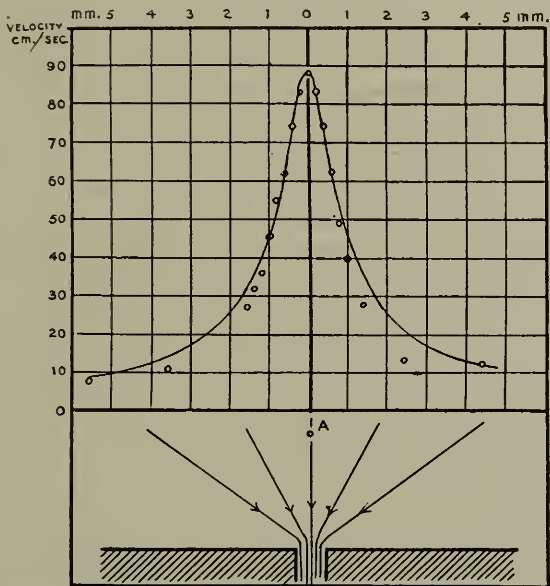
The linear hot-wire anemometer in the form just described has been extensively employed by the writer in a series of researches on the distribution of velocity in the flow of air between parallel planes, and considerable experience has been gained as to the most efficient method of using the instrument. In a paper already referred to [12] the writer has set out in some detail data as to the resolving power, upper and lower limits of correct velocity registration, life of wires, various sources of error, etc., which may be of use to experimenters wishing to employ the linear anemometer in aërotechnical investigations. For detailed directions as to the selection and calibration of anemometer-wires reference should be made to the writer's paper [12] already mentioned.

Although it is possible to determine the constants of formula (14) from the dimensions of the wire and its electrical resistance constants, making use of the absolute determinations described in the first part of this paper, it is preferable to calibrate the wires directly by mounting the anemometer fork on some form of rotating arm, as that shown in Fig. 2 *a*, making the necessary correction for "swirl." Wires were usually calibrated over the range $V=60$ to 800 cm./sec., enabling the constants of formula (14) to be determined. The relation expressed in this formula between the velocity and the current necessary to maintain the wire at a predetermined temperature (and therefore resistance) has been tested experimentally for velocities as low as 17 cm./sec., and was found

[12] King, L. V., "On the Precision Measurement of Air Velocity by Means of the Linear Hot-wire Anemometer," *Phil. Mag.*, vol. 29, April, 1915.

to hold good within the limits of experimental error. Theoretically the linear relation mentioned is the asymptote to a transcendental curve expressing the true relation between heat-loss and velocity; it is shown, however, that to an accuracy of 2½ per cent. a linear

FIG. 4.



Test of anemometer readings at low velocities: 3-mil wire No. 7.

A short rectangular channel of width 0.75 mm., having a plate at right angles to its length fitted flush with its upper extremity, was set up in the manner illustrated in the lower part of the figure. By means of suitable connections to a gasometer, air from the room was drawn into this channel under a constant pressure-difference of 2.35 cm. water. The distribution of flow at a sufficient distance from the opening of the channel is approximately that which would be set up in a perfect fluid by a distribution of sinks along a line coinciding with the opening of the channel into the plane mentioned. In the neighborhood of a plane bisecting this slit at right angles, where the velocity is measured by the portion of the anemometer-wire between potential terminals, the distribution of velocity is approximately radial. Taking a set of axes (x, y) having as their plane the diametral plane just mentioned, with origin at the centre of the slit, and measuring the axis of y along the direction of the channel, the velocity at any point (x, y) is approximately given by $V = V_0\sqrt{y^2/(y^2+x^2)}$, V_0 being the maximum velocity at $x=0$. The anemometer-wire, represented by A in the figure, was set by means of a micrometer-screw in various positions in the plane $y=3$ mm.; the observed velocity distribution thus obtained was compared with the theoretical by choosing V_0 to agree with the experimental value at $x=0$. The figure shows that the readings of velocity are fairly accurate for velocities as low as 12 cm./sec.; the deviations are possibly due to the limitations of the simple formula employed in calculating the theoretical velocity distribution.

formula of the type (14) may theoretically be employed when the velocity is as low as that given by the relation $Vd = 1.87 \times 10^{-2}$, V being expressed in cm./sec. and the diameter d in cm. For a 2½-mil wire this limiting velocity is as low as $V = 2.9$ cm./sec.,

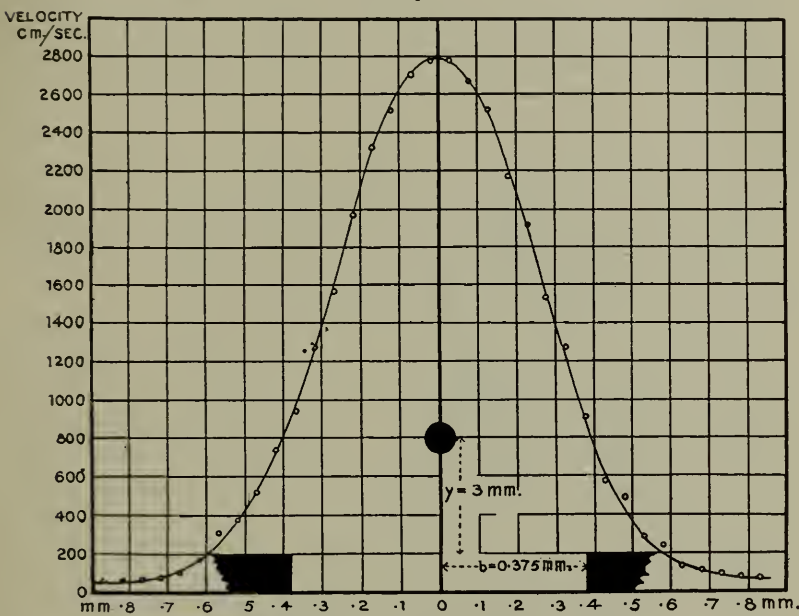
probably much lower than the lower limit imposed by the disturbing effect of the free convection current. Some information on this point can be derived from the experiment described under Fig. 4, in which the distribution of the flow of air into a slit in a plane is measured and compared with that calculated from theory. The evidence there discussed points to the fact that the anemometer registers velocities as low as 15 cm./sec. with an accuracy of a few per cent. For use in low-velocity measurement it is, however, more satisfactory to calibrate the anemometer over the range which it is designed to measure in practice.

At high velocities the relation (14) was tested for velocities as high as $V=900$ cm./sec., the usual upper limit at which anemometer-wires were calibrated by the writer in practice. From experiments on the flow of air between parallel planes, it appears that the calibration formula may be extended to velocities as high as 2800 cm./sec., making use of a 3-mil wire. An example of a test on this point is discussed under Fig. 5: the distribution of velocity of a stream of air issuing from a channel 0.75 mm. in width was measured at intervals of 0.05 mm. When the resulting curve, which attained a maximum of about 2800 cm./sec., was integrated to obtain the total flow in cm.^{3} per second, a fair agreement was obtained with the value of the total flow measured from the rate of fall of the gasometer, the pressure-difference over the length of the channel remaining the same in the two cases. Above this velocity it was found difficult to work with wires of the usual length of about 5 cm., as transverse vibrations are liable to be set up which invalidate the readings and tend to break off the potential leads, while the tension on the wire required to destroy synchronization with the free period of a stretched wire in an air-current is near the breaking-point of the wire. The upper limit of velocity measurement might be increased almost indefinitely by shortening the wire or by using stouter wire; this step results, however, in diminished sensitivity and resolving power, while in the use of stouter wire the working currents increase rapidly and the apparatus has to be specially designed to meet the resulting heating effects.

If the change of velocity just detectable by the instrument is denoted by δV, the ratio $V/\delta V$ which defines the *resolving power* of the anemometer is expressed in terms of that of the ammeter employed in connection with the apparatus; it is shown, in the

writer's paper on precision anemometry,[12] that with an ammeter reading to 0.002 ampère the resolving power of a 2½-mil wire at $V = 800$ cm./sec. is about 140, and the change of velocity just detectable is about 6 cm./sec.

FIG. 5.



Test of anemometer readings at high velocities: 3-mil wire No. 7.

The distribution of velocity illustrated in Fig. 4 was measured by setting the anemometer-wire in various positions by means of a micrometer-screw in a plane at a distance $y = 3$ mm. from the upper extremity of the channel described under Fig. 3. The dimensions of the channel were: width, $2b = 0.75$ mm.; breadth, $d = 5.08$ cm.; length, $l = 5.06$ cm. Integrating this velocity-distribution between the limits $x = \pm 0.92$ mm., the total flow per unit breadth of channel is 182 cm.^{3}/sec. under a pressure-difference of 11.5 cm. water. From a series of observations on the rate of fall of the gasometer for various pressure-differences, the total flow for breadth d was obtained, and hence the flow per unit breadth, assuming approximately uniform distribution of conditions over the breadth. From the curve connecting this flow with the pressure, the value per unit breadth corresponding to a pressure-difference of 11.5 cm. water came out to be 196 cm.^{3}/sec., in fair agreement with the value obtained from the anemometer measurements; the latter is probably an underestimate, owing to the destruction of momentum of flow as the jet travels through the stagnant air in this region. The low velocities beyond the edges of the channel are due partly to a "diffusion" of the jet owing to its dragging action on the quiescent air through which it is flowing, and at a greater distance to an indraught of air from the surroundings into the moving air of the jet. The distribution of velocity over the channel approximates fairly well to a parabola.

Among the sources of error which have to be guarded against in hot-wire anemometry, the most important are those arising from variations of atmospheric conditions. When the anemometer-wire is heated until its resistance attains a predetermined value the temperature reaches an absolutely fixed value, while

the heat-loss depends chiefly on the difference between the temperature of the wire and that of the surrounding air. As a result, fluctuations of atmospheric temperature will affect the calibration constants: in some applications it is of advantage to employ the wire at a high temperature (about 1000° C., or at a red heat), in which circumstances the fluctuations of room temperature likely to occur in a laboratory have no appreciable effect on the velocity measurements. If the wire is employed at a lower temperature (say 500° C.), as in continuous recording, the effects of variations of atmosphere temperature can be compensated by the introduction into the Kelvin Bridge circuit of special compensating coils.[13] In the writer's paper just referred to, it is shown that fluctuations of atmospheric pressure and variations of relative humidity have comparatively little effect on velocity determinations by means of the hot-wire anemometer.

In the analysis of velocity-gradients and in other researches of this type the writer has found it advantageous to employ the wire at a dull-red heat, as conditions of flow can then be conveniently judged by inspection. In these circumstances a limit is set in the direction of the highest temperature which it is possible to employ by a slow progressive increase in the resistance of the wire due to "evaporation"; this effect, which will be referred to as "aging," increases for very thin wires, and in practice sets a lower limit to the diameter of the wire which it is possible to employ for any continued series of observations at about 2½ mils. Experience has shown that in the case of a wire of this diameter the "aging" becomes distinctly noticeable after the wire has been employed to measure about 1000 velocities. In precision measurements of velocity it is advisable to recalibrate the wire at intervals of about 500 observations; when possible, the wire should be employed at a much lower temperature, in which case the difficulties due to "aging" are negligible.

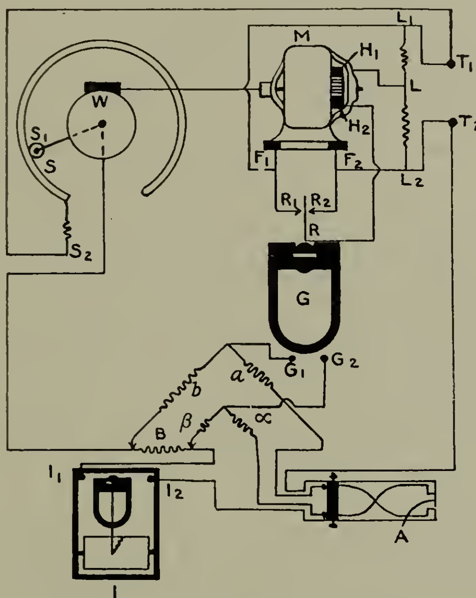
As many technical applications of the hot-wire anemometer require continuous observations of air-velocity to be made, there is no difficulty in designing a means of obtaining a continuous record easily interpretable in terms of wind-velocity.[14] In Fig. 6

[13] For details see the writer's paper (footnote 12), pp. 571–573.

[14] King, L. V., "Improved Means for Determining the Rate of Flow of Fluids," *British Patent Specification*, No. 18,568, 1914.

is shown one of the several possible arrangements whereby the resistance S of the adjustable rheostat may be automatically adjusted so that the galvanometer G is always balanced, while the current i through the anemometer-wire is registered, on a recording ammeter I, giving a record easily interpretable in terms of wind-velocity. The moving contact of the rheostat, S_1, is attached to an arm which can be caused to rotate in either direction by means of a worm-gear W connected to the shaft of a

FIG. 6.



Design for recording hot-wire anemometer.

small direct-current motor M, whose field F_1F_2 is permanently connected across the line terminals T_1T_2. Across the terminals T_1T_2 are inserted in series two equal high resistances L_1L and LL_2: one of the brushes is connected to L and the other to the movable pointer R of a sensitive galvanometer-relay G; the terminals L_1 and L_2 are connected to the contacts R_1 and R_2. The remainder of the apparatus corresponds to the connections shown in Fig. 3 *b*, the galvanometer G being replaced by a galvanometer-relay and the ammeter by a recording instrument. The mode of operation of the recording anemometer can be easily followed

from Fig. 6 when the anemometer-wire undergoes a change of temperature, and therefore of resistance, due to a change of wind-velocity, the galvanometer is thrown out of balance and contact is made with one or other of the terminals R_1 or R_2; current is allowed to pass through the armature of the motor M in one or the other direction, thus causing a corresponding rotation of the shaft and worm. The direction of rotation is so arranged that the resistance S_1S_2 is altered in such a way that the movable contact R of the relay-galvanometer is brought back to the position of no contact. It is estimated that the total weight of the recording anemometer can be kept under sixty pounds, so that a design of this type should be specially suited to taking records of air velocity from aëroplanes or airships in actual flight.

VARIOUS APPLICATIONS OF THE HOT-WIRE ANEMOMETER TO TECHNICAL PHYSICS.

The high resolving power, comparative freedom from serious corrections, together with extreme sensitiveness at low velocities, make the linear anemometer a very suitable laboratory instrument for use in studying various problems of gas-flow. In particular, the instrument has recently been employed by the writer in a detailed investigation on the flow of air between parallel planes with especial reference to the study of criteria of stability of laminar flow; in fact, the system of precision anemometry described in the present paper was evolved with special reference to this problem.

In the field of modern aëronautics the linear anemometer would appear to have a wide field of usefulness in the study of the inner mechanism of "skin resistance." For instance, it is easily seen, from the preceding account of the instrument and of its actual performance, that it would be a comparatively easy matter to study the gradients of velocity in the neighborhood of thin planes held lengthwise in a uniform stream of air, or near the walls of a large-dimensioned channel, such as a wind-tunnel, to within a small fraction of a millimetre from the surface. As the phenomenon of skin-resistance, which is associated with the establishment of turbulence, takes its origin in the region close to the rigid boundary, it would seem that valuable information on "eddy-motion" under such conditions might be obtained by this means.

It is only necessary to turn over the pages of any of the recent reports of the aërotechnical societies of various countries to notice numerous tests in which the use of the hot-wire anemometer might be made to yield valuable information. For instance, in the "Technical Report of the Advisory Committee for Aëronautics,"[15] 1912–13, Jones and Paterson give a detailed investigation of the distribution of pressure over the entire surface of an aërofoil; a measurement of velocity-distributions taken in the same circumstances would prove of considerable interest in the interpretation of the results. In the study of complex problems relating to the design of aëroplane propeller blades and the fans of rotary blowers there should be no serious difficulty in mounting a calibrated anemometer-wire on the blades and making electrical connections through slip-rings to the Kelvin bridge, which lends itself specially well for the purpose.

From the point of view of the aviator, a knowledge of the structure of the wind is of great importance. Initiated by Langley many years ago, this branch of knowledge is now being made the subject of continuous observation.[16] In this connection the investigation of gusts and their connection with large-scale eddies is a branch of meteorology for which the hot-wire anemometer would seem especially applicable, as by employing a thin wire the lag to variations in velocity is extremely small. In this connection there should be no difficulty in developing a special form of recording anemometer based on the principle of the oscillograph for reading even minute variations of wind-velocity. Eddy-motion in the atmosphere has recently been made the subject of an interesting theoretical contribution by G. I. Taylor[17] which promises to have important developments and applications.

In many branches of engineering the problem of heat trans-

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[15] "Technical Report of the Advisory Committee for Aëronautics," 1912–13: London, Darling and Son. 1914. A valuable survey of the field of aërodynamics has recently been given by Hunsaker J. C., "A Review of Hydrodynamical Theory as Applied to Experimental Aërodynamics," paper presented at the meeting of the International Engineering Congress, San Francisco, Cal., September 20–25, 1915.

[16] See "Report on Wind Structure," by J. S. Dines: "Technical Reports of the Advisory Committee for Aëronautics," 1908–09 to 1912–13.

[17] Taylor, G. I., "Eddy-motion in the Atmosphere," *Phil. Trans. Roy. Soc. London,* vol. 215 A, 1915, pp. 1–26.

mission is an important one and one whose laws have not as yet been accurately formulated. In particular, the design of electrical machinery and equipment requires the evaluation of heat losses by free convection to be made with as much accuracy as possible.[18] In the investigation of the laws of free convection in simple cases the linear hot-wire anemometer as developed by the writer would seem capable of being employed with advantage. By employing an extremely small measuring current and a sensitive galvanometer, the hot-wire anemometer may also be employed as a resistance thermometer capable of measuring temperature to 0.1° C., or, with special precautions, to 0.01° C. In this way it would be possible to explore both temperature and air-velocity in the immediate neighborhood of surfaces being cooled by free convection. As regards more specific problems, the linear anemometer would seem capable of being easily adapted to exploring the distribution of air-currents in electric generators; *e.g.*, an anemometer-wire could be employed to analyze the velocity-gradients in the air-gap between the armature and pole-pieces of a generator and connect these with heat-losses measured in the usual way.

Another important branch of engineering requiring as accurate a knowledge as possible of the laws of heat convection is the designing of modern internal combustion engines, both as regards cooling by water circulation and by forced-air draught.[19]

From the theoretical point of view, considerable progress has recently been made by Taylor[17] in formulating the mechanism of heat-transfer from a surface into a fluid under conditions of eddy-motion. The final experimental verification of the formulæ there developed will require numerous experiments to be carried out on heat-losses under these conditions. In this field the linear anemometer would seem capable of being employed with advantage in the measurement of both velocity and temperature gradients. An important point in this connection is its property of giving a consistent measure of turbulent velocity,[20] under which

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[18] A detailed review of this aspect of the subject is given by Langmuir, "Laws of Heat Transmission in Electrical Machinery," *Trans. A. I. E. E.*, 32, 1913, pp. 301–323.

[19] Note in this connection interesting papers by Lanchester, F. W., and Stanton, T. E., "Surface Cooling and Skin Friction," Report of the Advisory Committee for Aëronautics, 1912–13, pp. 40–47.

[20] King, L. V., *Phil. Trans. Roy. Soc.*, 214 A, 1914, p. 407.

conditions the use of a pitot-tube is difficult to use and uncertain in its readings.

Closely allied to problems of heat convection are those of evaporation or diffusion of vapors from liquid surfaces. From the theoretical point of view the mathematical statements of the two problems are practically identical, so that the theoretical formulæ which have been found to apply to calculations of heat-losses will probably be found to apply to evaporation problems as well. In practice it is obvious that rate of evaporation from a liquid will depend very largely on the conditions of air-velocity in the immediate vicinity of the surface. In investigations on these subjects the linear anemometer would seem capable of giving valuable information on velocity gradients and their connection with rates of evaporation. The subject is one of considerable practical importance, and has recently been studied in some detail by meteorologists.[21]

McGILL UNIVERSITY,
December 11, 1915.

A New Glass and an Application of the Low Reflectivity of Glass for Radiant Heat. E. C. SULLIVAN and W. C. TAYLOR. (*The Journal of Industrial and Engineering Chemistry*, vol. 7, No. 12, December, 1915.)—A glass has recently been developed at the Corning Glass Works, Corning, N. Y., which is unique among borosilicate glasses in that it combines very low thermal expansion with resistance to attack by reagents. It is of simple chemical composition, being free from heavy metals and metals of the magnesium-calcium-zinc group. Its characteristic properties are due, in part, to very high silica content, which incidentally has necessitated special technic for its melting and working. Its specific gravity is 2.25, and mean linear expansion coefficient (19°–350°), 0.0000032.

Culinary ware made of the glass was found to bake food more rapidly than earthenware or metal. The reason for this lay, in the case of the metal, in the greater reflectivity of the metal for radiant energy. Experiments showed that its resistance to fracture from a blow is greater than that of enamelled earthenware or ordinary crockery.

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[21] For a detailed bibliography of the subject see papers by Livingston, Mrs. Grace J., *Monthly Weather Review*, 1908, pp. 184, 301, 375; 1909, pp. 68, 103, 157, 193, 248.

Uses of Platinum. J. M. HILL. (*Mineral Resources of the United States, Calendar Year, 1914—Part I,* United States Geological Survey, 1915.)—One of the most important uses of platinum is as a catalyzer in what is technically known as "contact mass" in the manufacture of fuming sulphuric acid and sulphur trioxide. There are several kinds of "contact mass," the two most used in this country being on asbestos or magnesium sulphate bases. The mass is made by soaking the base in solutions containing platinum chloride and afterwards heating it. This treatment results in a more or less complete distribution of very fine particles of metallic platinum throughout the mass. Some "contact mass" contains as much as 7 or 8 per cent. by weight of platinum, and other manufacturers make a mass containing as little as 0.2 per cent. metallic platinum by weight.

It is impossible at this time to state the quantity of platinum used in the sulphuric acid industry in this country, but it is believed that the loss of platinum in well-regulated practice is very small. The platinum does not enter into the chemical reaction, but rather acts as an exciter in the formation of sulphur trioxide, which, on combination with water, yields sulphuric acid.

Platinum dishes and utensils of many kinds are still a necessity in chemical laboratories and in many chemical industries, but the uses of the metal in the electrical industry are each year becoming fewer. In the manufacture of incandescent lamps a large quantity of platinum was formerly used, but at present wires made of nickel-chromium alloys or metallic tungsten or metallic molybdenum are used. The resistance wires of electric furnaces and heaters at one time contained considerable platinum, but metallic molybdenum has now to a considerable extent replaced the more expensive metal. Formerly the electric ignition points of gas engines were made of platinum, but it is believed that most of the spark-plug points now used are made of metallic tungsten.

The dental industry once used a large quantity of platinum in making artificial teeth. It is understood that recently metallic molybdenum plated with platinum is widely used rather than pure platinum. The art of platinum plating has now been perfected to so remarkable a degree that jewellers are no longer under the necessity of using so much platinum as formerly in making jewelry, though platinum is still considered the best setting for precious gems. This use of platinum, however, is somewhat subject to the reigning fashion. Of ininterest in this connection is a bill which was prepared by the National Jewelers' Board of Trade of New York, early in 1914, for presentation to the New York Legislature, making it a misdemeanor to mark inferior jewelry "platinum" unless it is 0.950 fine or contains 95 per cent. platinum group of metals. A somewhat similar law was passed by the Swiss Federal Council, to be effective March 1, 1914. This law provides that "Upon request of the manufacturer, seller, or purchaser, articles having a minimum platinum content of 95 per cent. will receive the official stamp of the Alpine goat."

THE DEVELOPMENT OF A DYNAMIC THEORY OF SOIL FERTILITY.*

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INTRODUCTION.

EXCEPTING only the healing art, there is probably no branch of human inquiry which has received more attention than the relation of crop production to soil factors, or, as it is more popularly styled, "soil fertility." Again, excepting only medicine, there is no subject about which there are as many and firmly held popular misconceptions. And with the same exception, probably, there is none about and of which there have been so many and such bitter controversies and polemics. It is inevitable that a comparison between the progress of medicine and agriculture should come to mind, for these twin arts were through the ages the incentive to the development of what we are pleased nowadays to call pure science. The science of chemistry in a very real way has always been regarded as the handmaiden of the sister arts of medicine and agriculture from the time of the early alchemists until to-day, when a share of her service is demanded also by the younger sister, manufacture or industrial arts. Many of the past controversies of chemistry have been controversies over agricultural theories, and a very large share of the epoch-marking items in the progress of chemistry has come from consideration of agricultural problems. The histories of chemistry and of agriculture are inseparably intertwined, as are those of chemistry and medicine. It is to be regretted that the development of the art of agriculture has lagged behind that of medicine. But progress there has been; the light of promise is shining brighter than ever before; and

* Presented at a joint meeting of the Section of Physics and Chemistry and the Philadelphia Section of the American Chemical Society held Thursday, October 28, 1915.

it is the purpose of this lecture to show the gradual development of scientific views, based on a large body of established facts, to a point where it is manifest that the time is in sight when agriculture will have passed from the avocation of the peasant to the profession of a learned man, and that, to be successful, the farmer of the future will have to possess the same type of training, education, and equipment that is now recognized as necessary for the physician, lawyer, or engineer. The time has arrived when our universities should recognize the *desirability* of providing proper equipment in faculty personnel and laboratory facilities for advanced work or "research" in crop, plant, and soil problems; and the time is probably near when they will be forced to acknowledge the *necessity* of doing so.

To carry out the purpose of this lecture it will not be necessary, nor will it be desirable, to attempt a complete presentation of the various individual views that have appeared from time to time. Fortunately, the early literature has been summarized in readable and entertaining accounts, as by Shenstone in his "Life and Work of Justus von Liebig" (The Century Science Series), and, more recently, by the accomplished director of the Rothamstead Experimental Station, Dr. Russell, in "Soil Conditions and Plant Growth" (Monographs on Biochemistry). The later literature is easily accessible, and the last few years have seen the production of numerous texts in which it is summarized.

It will be practicable here to sketch only an outline of the steps in a progression from the early crude deductions based on slim and often faulty evidences, through the masterly generalizations made possible by an improving scientific technic, to the present advanced stage of a large and orderly body of knowledge, bristling with suggestions for further inquiries, and supported by the technical equipment of the most highly developed of the physical sciences.

EARLY THEORIES.

While farming has always attracted a few people, gardening has always had its charms for the many. Hence it is natural that the problems of seed germination, growth of plant, and kindred subjects should have attracted the attention of thoughtful men in all times, and references could be found in the liter-

ature of all known times. The agricultural literature of later Roman times had reached considerable proportions. But, from the modern viewpoint, the first important work on the theory of plant production is that of van Helmont (1577–1644), who carried out a planned experiment, growing a willow shoot in a vessel filled with soil and so protected that nothing, so far as he knew, was added to the soil but water. In five years the willow had increased in weight from 5 pounds to upwards of 169 pounds, while the soil mass of some 200 pounds had decreased but a few ounces. Influenced by the philosophical views of his time, van Helmont thought he had found the explanation of plant growth, and that water was the "principle" of fertility. Many years later Priestley (1775), noting that air vitiated by animals was apparently made pure by growing plants, tested the problem experimentally with mint plants. But his compeer, Scheele, insisted that growing plants, like animals, vitiated the atmosphere, and not even the discovery of oxygen, made independently by Priestley, as well as by Lavoisier, gave the true explanation until the work of Ingen-Housz (1779) and Senebier (1782) showed that plants absorb carbon dioxide only in the light and that oxygen absorption takes place in the dark. The modern conceptions of the function of chlorophyll came, of course, much later. There has been in this line of inquiry a steady progression of knowledge and theory, with the final acceptance of a dynamic viewpoint.

But meanwhile the functions of the soil were not entirely ignored. Glauber (1656), shortly after van Helmont's classical research, gave a logical and at the same time an apparently sufficient demonstration that saltpetre was the "principle" of fertility. Later, Mayow (1674) found that the saltpetre content of the soil fluctuated from season to season, and explained his observations by the hypothesis that the nitre of the soil is "sucked out" by growing plants. These investigations were, logically, forerunners of the later observations of Boussingault (1838), who advanced arguments and experimental evidence for the fixation of atmospheric nitrogen by growing plants, and of the still later work of Liebig, Warrington, Lawes, Hellriegel and Wilfarth, Widnogradsky, and a host of brilliant modern investigators which has developed into the fascinating field of soil bacteriology and nitrogen fixation by living organisms. And, from

the nature of the case, the phenomena of living organisms are dynamic in character.

Again going back, we find Boerhaave (1727) to be the first, apparently, to recognize the importance of the soil solution as the nutrient medium for plant growth. But Boerhaave's views were by no means as influential as those put forward by Jethro Tull (1730), who, recognizing root pressure as great and of obvious importance, considered it a provision of nature to force the finer soil particles into the "lacteal mouths" of the roots where these particles became the "proper pabulum" for the plants. Tull's very real contributions to husbandry in the way of inventions of tillage machines and observations on tillage methods, together with a vigorous literary style, good observational powers, and forceful deductions, gave him a widespread and great authority.

Following Tull's time, the development of analytical chemistry led to the recognition that mineral substances were of value or necessity to growing plants. It was frequently observed from the earliest time that minerals, added to the soil, increased plant growth. Finally came the work of Senebier and de Saussure, Boussingault, and Liebig, not to mention numerous lesser lights, confirming the importance of mineral nutrients, introducing the rapidly developing technic of analytical chemistry, the use of pot and water cultures and plot tests, essentially the methods most used to-day. Although it was recognized by many that the addition of mineral substances to the soil frequently increased plant growth, and that the ashes of plants contained minerals, nevertheless the theory that found most favor and was most widely accepted is that known historically as the "humus" theory.

THE HUMUS THEORY.

The organic complex in the soil resulting from the decay of plant and animal tissues was generally supposed to be the main food of plants. It is similar in composition, and is (apparently, at least) affected in solubility by the addition of salts. It is certainly rendered more soluble by alkalies, hence by plant ash, and thus the action of mineral substances in improving plant growth could be explained. It has been recognized from time immemorial that soils rich in humus are as a class more productive than soils poor in humus. Without pausing to go into complete detail, it is read-

ily understandable that in times when syllogisms were more appreciated than laboratory or field experiments men's minds could easily accept the humus theory as the most plausible explanation of soil fertility.

The humus theory was the dominating one when, about 1840, Liebig commenced his investigations in agriculture and laid down the basis for a systematic, scientifically-developed branch of human knowledge, essential to mankind's happiness and welfare; namely, agricultural chemistry. Liebig's first important work in this field was a comprehensive examination of the validity of the humus theory by subjecting it to the tests of quantitative chemical analyses. He showed that humus was very slightly soluble in water, except in the presence of considerable amounts of alkali. Even freshly-precipitated humus was rendered less soluble either by drying or by freezing, hence changing weather conditions would render it less rather than more soluble. If insoluble in the soil water it can not be taken up by plants through their roots. To test the possible importance of alkalies in rendering the humus more soluble, Liebig computed the carbon content of soils and found there was far less than in the crops produced by the same soils. Furthermore, careful and proper cultivation resulted not only in larger crops, and hence more carbon in plant tissue being produced, but simultaneously there was an increase in humus and carbon in the soil. And, finally, he pointed out that if humus be the result of the decayed plant tissue, there must have been plants before there ever was any humus, which requires an explanation of how the primordial plants existed.

Liebig, having shown that the carbon of plant tissues can not come from the earth, pointed out that it must come from the air, and, as had already been made evident by the work of Priestley, Ingen-Housz, Senebier, and de Saussure, there is an absorption of carbon dioxide with liberation of oxygen by growing plants while in sunlight, with a reverse absorption of oxygen, with sometimes an elimination of carbon dioxide, when these same plants are in the dark. But Liebig went further and showed that the oxygen and hydrogen in plant tissues are present in about the same proportions as in water. De Saussure had already shown that water was taken up by plants and utilized in tissue formation. Hence, the oxygen taken up by carbon

dioxide being an unnecessary excess to the plant, its elimination is natural and to be expected. It follows that for every volume of carbon dioxide absorbed in the formation of plant tissue an equal volume of oxygen is added to the atmosphere. Liebig recognized that here was the explanation of the sustained constancy of the oxygen content and carbon dioxide content of the atmosphere, and that this continually-sustained interchange of oxygen and carbon dioxide by vegetation was necessary for the continued life of animals. He supported his arguments by analyses of air from old, long-buried vessels, from various other sources, and by computations of the probable duration of animal life if there were no such renewal of the oxygen supply. To the objection that the very small normal content of carbon dioxide in the atmosphere, less than one-tenth of one per cent., is insufficient for the support of vegetation (*i.e.*, its rate of growth), Liebig again brought the quantitative method. By determining the absorption of carbon dioxide on a surface washed with a lime suspension, he found that in a given time there was five or six times more carbon dioxide absorbed than was taken up by an equal area of leaf surface. From these deductions Liebig next made clear that the metabolic processes in plants and animals were essentially different. Although the contrary view, based on analogy, was the popular one, Liebig's great authority prevailed. The times were "ripe." A half century earlier, as we now know, Lavoisier had clearly seen the truth, but his opinions were not made public until many decades (1862) after his untimely murder. But Boussingault and Dumas, of scarcely less authority in scientific matters than Liebig, expressed similar views to his in 1841. And, in England especially, agriculture had become popularized with the better-educated and leisure classes, there was much discussion of agricultural subjects, and men's minds were receptive for the teachings of the great German savant, at that time very popular in England and with an immense prestige in the scientific circles of France.

MINERAL THEORY.

Having demolished the humus theory, Liebig turned his attention to the mineral constituents of plants. It had been noted by van Helmont, in his famous experiment already cited, that there was a small loss of the soil, and it was repeatedly

shown by subsequent investigators that plants contained mineral substances which remained in the ash when they were burned. It was also well known that plant ashes were alkaline, which was quite widely accepted as a proof, in early times, that plants generated or created alkalies. When Liebig began his work on agriculture the exponents of the humus theory, supported by so great an authority as Berzelius, recognizing the value of mineral substances when applied to the soil, explained them as stimulants, but not as plant foods or as essential to plant growth. Liebig immediately instituted, at the famous Giessen Laboratory, a long series of investigations of the composition of plant ashes and of the mineral content of soils. Meanwhile other workers were active, as Ville, the apostle of scientific agriculture in France, and Knop, famous because of his studies of plants in water cultures, with numerous earnest colleagues of equal distinction and importance. It was soon found that some nine or ten mineral constituents were always present in plants, and that plants could not be grown in artificial media unless these constituents were present, each and every one.

This led to the idea of supplying mineral plant food artificially to increase immediate plant production, to build up and increase the fertility of the soil, and to ward off soil exhaustion, etc., subjects quite familiar in the current writings of to-day, especially in connection with the great "conservation" movement now stirring the public consciousness and, let us hope, the public conscience.

The first "chemical manures," or commercial fertilizers, as we call them to-day, were prepared on the assumption that they should be of very slight solubility in water, that they might simulate the character of the natural soil components, and that they might not be leached from the soil too rapidly. In spite of many notable successes from their use, there were a great many disappointments and, on the whole, the results, especially in practical farm work, were far short of expectations. The experiments of Way suggested an explanation. It has been known, from the time of Aristotle at least, that soils are absorbents of mineral substances as well as of soluble organic materials. Way's quantitative investigation showed that many mineral substances were abstracted from water solutions or

"fixed" by the soil when the solution was percolated through the soil. Apparently, Way considered that in most cases there was a metathetical reaction between the soil components and the dissolved substance. Liebig followed up Way's work enthusiastically and vigorously, considering the fixation of the dissolved substance on the surface of the soil particles as due to a "physical combination," or, as we now term it, to adsorption. Water-soluble mineral fertilizers would be held in physical combination when applied to the soil, ready to reënter the soil water as it was depleted by the plants.

This idea also explained the disappointing results of soil analyses, where it was often found that soils which contained the larger percentages of mineral nutrients or "plant foods" were not always the more productive. Quickly there was developed the idea that there is a real distinction between the mineral nutrients *in toto* and the proportions which are "available," immediately or ultimately. A great many methods, frankly empirical and with very slight scientific basis, have been devised to analyze chemically the soil, usually by analyzing an extract obtained by heating the soil with an acidified aqueous solution. An enormous amount of data has been thus accumulated, unfortunately of very little value, either theoretically or practically. But this idea of availability has dominated by far the greater part of the chemical work on soils and plants for the half dozen decades succeeding Liebig's work, and we even hear to-day of chemically available, physically available, and biologically available plant food.

Of only lesser importance as a guide in soil work has been the so-called Liebig's "law of the minimum;" *i.e.,* if an essential mineral plant food be absent from a soil, or present in unavailable form, or available but below a certain minimum amount, it will determine the growth of plants on that soil, irrespective of the amounts of other mineral substances present. This "law" has also been broadened by some writers to cover water and even bacteria.

THE DYNAMIC VIEWPOINT.

Following the epoch-making work of Liebig, there has been an enormous amount of work, much of it of very great value, much of it like a great part of Liebig's own work, incorrect and doomed to oblivion or to renewed life in modified forms. For

instance, van Bemmelin, recognizing adsorption phenomena in soils, the crumbing and decrumbing of soils induced by various substances, to be very similar to flocculation phenomena in recognized colloids, advanced the idea that colloids are predominating components in soils; and this view has recently been very forcefully presented by Russell: "If we regard the mineral particles the skeleton of the soil, we must look upon the colloids as clothing it in many of its essential attributes." Unfortunately, no one has any clear, much less precise, idea as to what is a colloid, and Russell would be quite correct, though less impressive, perhaps, if instead of colloids he should say the very finely-divided components of the soil with their relatively enormous area of active surface.

Out of this great mass of scientific endeavor there have come a number of highly-developed and distinct branches of science; as, plant physiology, plant pathology, ecology, soil bacteriology, and soil chemistry and physics. All of them are concerned fundamentally with the theory of soil fertility. Following the common course of development in every natural science, these subjects have gradually been developed from static viewpoints to dynamic viewpoints, more or less consciously recognized. Apparently there has been an exception in the case of soil chemistry, owing to a too-narrow view of the plant-food theory of mineral nutrients, an overweening appreciation of the authority of Liebig, and an unreasonable dependence on the all-sufficiency of analytical chemistry. In reality, this subject has also reached the state of development where its problems must be attacked from the dynamic viewpoint; and very substantial progress has been made in this direction, as will be apparent from the following sketch of our present knowledge of soil phenomena.

First, consider the growing plant. From the very fact that the plant is growing, plant phenomena are phenomena of change; that is, they are of a dynamic character. The absorption of carbon dioxide by the leaves and its elaboration into organic tissue is a dynamic phenomenon. So, also, is the absorption of nutrients and other substances from the soil solution by the root system. In a living plant the root is continually moving through the soil by growth processes. If this movement be arrested or prevented the plant will soon die. Back of the root tip there is the area of absorption where the soil solution enters the plant.

The mechanism of the absorption is very far from being understood. Usually it is more or less glibly described as an osmotic process, leaving very much to be desired in the way of explanation. We know that organic residues of plant metabolism are left in the soil; that enzymes, probably for protective purposes, are developed by growing roots. We also know that all the mineral substances taken into the plant during its growth and development do not permanently remain therein, but are partly eliminated through leaf and partly, probably, by root excretion also. But all these phenomena are phenomena of change, are dynamic in character, and the comparatively rapid development of knowledge of plant processes in recent years has undoubtedly been due to the gradual acceptance of the dynamic viewpoint, whether consciously or unconsciously.

Defining soils, for convenience, as those areas of the solid surface of the earth adapted to the growth of crop plants, it has been found that each and every soil is quite complex in composition. There is an old generalization that everything ultimately finds itself in the sea. But on the way to the sea most things pause for a time in the soil. The products of every activity—natural and artificial—are likely to be found in any soil. And the presence of any or all of these products may have some influence on its capability for crop production.

Recent investigations have shown that practically every inorganic element for which reliable methods of analysis are available is to be found in the soil. In a very careful investigation of some twenty-seven soils of known agricultural importance from widely-separated points throughout the United States east of the Mississippi River it has been possible to make quantitative determinations of practically every mineral element excepting molybdenum, gold and platinum. Molybdenum was found in some soils but not recognized in others, and gold and platinum were not specially sought, as of no particular interest in this connection. As to the minerals themselves, it has been shown that practically every common rock-forming mineral is present in every soil. The mineral complexity of any soil is far greater than that of a rock, probably due in the main to the large aggregate amount of soil transportation by the wind.

Likewise, humus, or the mixture of organic *débris* in every soil supporting vegetation, is always complex. Some forty or

more definite organic compounds, containing representatives of practically every known type of organic substances, have now been extracted from soils. Existing knowledge of the complete composition of the humus of any particular soil is very far from complete. It is probable that certain organic substances will be found common to all or most soils, while other substances will have an adventitious significance only. But the number of distinct organic species in any one soil is probably quite large.

The solid components of the soil are in various stages of subdivision, from gravel down to particles so small as to defy the powers of the microscope to recognize their limits. These very fine particles, silt and clay, may comprise only a small percentage of the soil mass, as in sandy soils, or much more than half, as in heavy clays. Mechanical separates of soils, between arbitrary limits, have been analyzed, showing that there is a tendency towards segregation of the constituents in different-sized particles. Humus, ferric hydroxide, potassium, phosphoric acid, and, in fine, all those constituents of recognized importance to plant growth, tend to segregate in the finest particles. These finest particles, in the aggregate, have an enormous surface which is thus exposed to the action of the soil water, and which also accounts for the pronounced adsorptive powers of soils, or, as Liebig found, the ability to form "physical compounds," as distinguished from chemical compounds.

The solid components of the soil are continually in motion. The transport of the soil material by water is very great and striking in the case of such a river as the Mississippi. But it is proceeding on lesser scales everywhere. No field is so flat but that there is some movement of the surface particles with every rain, and it is obvious that erosion is proceeding everywhere on the land surface of the earth, rapidly in some places, more slowly at other points. But of little, if any, less importance is the transport of soil material by the wind, although this is not recognized generally by the lay public. If the attacking power of the wind on the soil were as great as its transporting ability—which fortunately is not the case—it has been computed that the amount of soil material which would be blown into the Gulf of Mexico from the Mississippi Valley would be 4000 times that carried down by the river. Testimony of the carrying powers of the winds is furnished by deposits of soil material, frequently sup-

porting plants, on roofs, barren mountain tops, glaciers in Greenland, etc. Samples have been brought back from the polar ice which have been found to be ordinary soil material. Dust from the Sahara is blown across the Mediterranean into Europe every year, and has been traced so often as to be quite familiar. The most striking case, perhaps, is the Alaskan tundra, where a foot or two of soil material, supporting a luxuriant vegetation, is underlaid by perennial ice. No agency other than transport by the wind can explain the presence of this soil material. It is well known now that it is the common condition that the surface soil is lighter than the subsoil, due mainly to the fact that the finer soil particles have been blown out of the surface material. Moreover, the wind is in action all the time, or practically so, and carries material up hill as well as down. Soil material is continually being transported, deposited, and retransported, so that there is little wonder that soils are such heterogeneous mixtures. And, again, it is to be noted, it is the finest particles which are the most important in affecting crop growth which are the most subject to transport by water and wind.

There is another movement of the solid particles of the soil. It has been shown that every observable physical property of the soil which can be measured and which affects crop production is dependent upon the moisture content of the soil. If an air-dry soil mass be moistened, it expands or "swells up," and, as further moisture is added, the swelling continues until a certain moisture content is reached, after which further additions of water produce a rapid diminution of volume. Reversing the process (that is, drying out the wetted soil), there is first an increase of volume until the critical moisture content is reached, and then a gradual decrease. But the drying process does not follow the same path as the wetting process. There is an hysteresis, and continued alternate wetting and drying of the soil produces a natural packing of the soil material, such as must be taking place in the field with every cultivated soil. This is illustrated by the curves of Fig. 1. The only rational explanation of this hysteresis is that the soil particles move about among themselves with rearrangements of structure following change of moisture content. In the field the moisture content of the soil must be continually changing with the weather, hence

the soil particles must be continually in motion. Drying of the soil produces cracks, into which drops surface soil from the edges. Earthworms, beetles, and other organisms are continually transporting soil material. Movements associated with crumbing and decrumbing, and possibly other movements, are continually taking place. The soil particles must therefore be continually in motion, there must be more or less interchange of surface soil and subsoil taking place, and there must be more or less transport of soil material from place to place continually occurring. Of course, much of the most important part of the soil mass, from an agricultural point of view, is continually being lost in the sea and its tributaries, which loss is being met by the

FIG. 1.

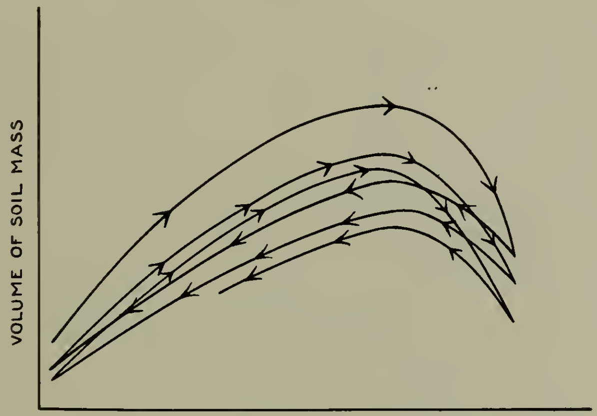


Diagram showing volume changes in a soil sample subjected to alternate wetting and drying. The arrows note the direction of the process. There is a "hysteresis" evidenced and a "natural packing" of the soil.

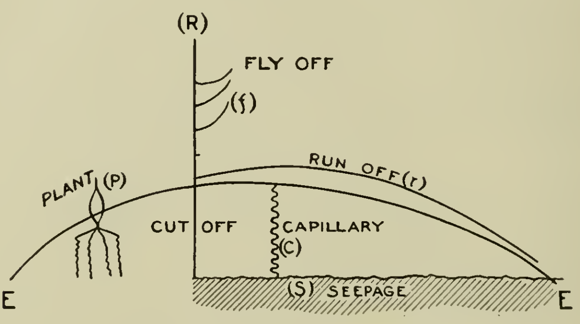
continual conversion of subsoil material into surface soil, through well-recognized agencies. It is clear that any and all phenomena involving the solid particles of the soil are phenomena involving continual change; hence they are dynamic in character.

There is, in every soil in proper condition for the growth of plants, an aqueous solution of the solid and gaseous components. This solution is, normally, disposed in the soil in the finer capillary spaces, but mainly in the form of films over the soil particles and aggregates of particles. At the critical or optimum water content the soil contains the maximum amount of water which it can, all the water being in films. Any increase

of water to the soil means some free water in the interstices, decrease of aëration, and a lessening of the optimum condition for plant growth. Any decrease of moisture below the critical moisture content means a redistribution and thinning of the films, with changes of stress on the floccules and a tendency to readjust the structure of the soil. Since, as noted above, the soil is always getting wetted or is drying out, there must be a continual movement of the soil solution, with continual change of stress, and more or less movement of the solid particles. Obviously the phenomena are dynamic.

The water forming the soil solution comes, of course, from the rain falling upon the soil. It will be well, therefore, at this point to consider the distribution of the rainfall; and, for clear-

FIG. 2.



Sketch of the disposition of the rainfall.

ness of exposition, the diagram in Fig. 2 appears to be useful. Let the line *EE* represent the surface of the soil, and the line *R* represent the rainfall (*R*). During precipitation there is a partial conversion of the rain to vapor, which the late Major Powell designated as the fly-off (*f*) in distinction from the run-off (*r*), or that portion of the rainfall which passes over the surface to the drainage channels. A part of the rainfall passes *into* the soil, going through the larger soil openings and moving at a rapid rate relatively, mainly under the influence of gravity. Consistently with Major Powell's terminology, this portion of the rainfall may be called the cut-off. In the soil the cut-off may be considered to divide into two portions. One of these, the seepage (*S*), moves through the soil at a rate determined by the character of the soil material, but relatively rapidly, and appears at the surface as a spring or bog or in some such way. More

or less mineral and organic matter is dissolved by the seepage water, so that all springs, ponds, lakes, rivers, etc., are soil solutions more or less diluted. But when the rain ceases there is an evaporation at the surface of the soil mass, a capillary drag or pull on the soil films is created, the resultant of the stresses being in the direction of the surface, and part of the cut-off water returns to the surface as capillary water (C), to ultimately join the fly-off. This rise of the capillary water is, in general, relatively much slower than the descent of the cut-off water and the movement of the seepage. Restating this description of the disposition of the rainfall in the form of an equation, we have:

$$\begin{aligned} R &= f + r + \text{cut-off} \\ &= f + r + s + C \end{aligned}$$

But the run-off, plus the seepage, is the drainage of the area. The drainage for most of the large cultivable areas of the earth surface has been found to be not very far from 26 or 27 per cent. of the rainfall. It is quite possible that for any particular small area the drainage may be a quite different percentage of the rainfall; but it is evident, from the nature of the case, that in general the drainage throughout a region can not vary much from the general average for that region. Likewise, while the fly-off may be a large percentage of a particular shower, or of the total rainfall in an arid region, generally, in a humid region it will aggregate but an almost vanishing percentage of the total annual rainfall. Assuming that the drainage and fly-off together may sometimes approach as much as one-third the rainfall, it then follows, from the equation given above, that C, or the capillary water, is equal to, or greater than, two-thirds of the rainfall. Such measurements as have been attempted indicate that on well-cultivated soils more than three-fourths of the rainfall not only enters the soil but again returns to the surface. It is evident that from the moment the rain-water strikes the surface of the earth until it either reaches the sea or evaporates into the air above the soil it is continually in motion, and all phenomena concerned with the soil moisture are of necessity dynamic in character.

Of the very many interesting and important consequences as well as speculations resulting from this consideration of the distribution of the rainfall, neither space nor time will permit description or discussion of more than one. Consider for a moment the plant illustrated by P in Fig. 2. Observe that the roots oc-

cupy but a small volume of soil near the surface, but that there is a stream of capillary water from the subsoil moving past the roots and bringing to them mineral substances in solution derived perhaps from minerals at considerable depths below the surface. In other words, during the growing season the principal supply of mineral nutrients used by the plant in its metabolic processes is derived probably from the subsoil, where the plant roots never penetrate. The faster the plant grows the faster it dries out the moisture along the roots, increases the capillary "pull," and thus automatically increases its food supply. It is clear, therefore, in spite of the popular notion to the contrary, that a chemical analysis of a small sample of surface soil is not an adequate or scientific method of determining the plant's food requirements. Yet this procedure has been the basis for much, if not most, of the experimental work on the fertilizer requirements of soils and of plants.

A consideration of the composition and concentration of the soil solution naturally follows. On its way through the soil to the surface the capillary water is in intimate contact with the solid soil particles for considerable time intervals, and these particles are composed of a large number of substances, inorganic and organic. Hence the soil solution is a somewhat complex one, and the solution products of the soil and subsoil are subject to a tendency towards concentration at the surface or in the upper soil layers. During a period of drought this accumulation of soluble materials may become quite pronounced, and in arid regions surface accumulations of salt mixtures known as "alkali" are unfortunately common. In humid regions, however, every rain carries back more or less of the accumulated soluble material in the cut-off water to the lower soil levels, where it may recommence its relatively slow ascent towards the surface.

Most of the definite mineral species found in soils may be regarded as salts very slightly soluble in water; and, usually, they are salts of a strong base, such as calcium or potassium, combined with a weak acid, a silicic or an alumino-silicic or ferro-silicic acid. A good illustration, for various reasons, is the mineral orthoclase which may be represented by the formula $KAlSi_3O_8$. Because of the nature of these salts, the dissolved portion is greatly hydrolized, thus:

$$
\begin{aligned}
KAlSi_3O_8 &\longrightarrow KOH + H_1AlSi_3O_8 \\
&\longrightarrow KOH + SiO_2 + H_1AlSi_2O_6 \\
&\longrightarrow KOH + 2SiO_2 + H_1AlSiO_4 \\
&\longrightarrow KOH + 3SiO_2 + HAlO_2
\end{aligned}
$$

The acid $HAlSi_3O_8$ is not known, but all the other compounds indicated are known as natural minerals and as alteration products of feldspar. It is by some such process as here indicated that most of the mineral plant nutrients in the soil solution are derived originally. But it is obvious that the concentration of the soil solution, if this were the only phenomena involved, could never be other than very small, except for temporary high concentrations near the surface of the soil during periods of prolonged drought.

Consider now the "physical compounds" first recognized by Liebig and justly regarded by him as of primary importance to soil fertility. These are far better understood nowadays as adsorption complexes. It is recognized that any solid surface, speaking generally, possesses the power to withdraw from a solution in contact with the surface and condense upon itself more or less of the dissolved components in the solution. Adsorption is a phenomenon dependent primarily upon the specific properties of the substances involved. But always there is a distribution of the soluble substance between the solvent and the absorbent, and, as one concentration changes, coincidentally there is a change in the same direction in the other concentration. For instance, if a soluble potassium salt be added to a soil in good moisture condition there will be an increase in the concentration of the soil solution, but at the same time there will be an increase in the concentration of the adsorbed potassium on the surfaces of the soil particles. Not only is the specific adsorption of the soil surfaces very high for most components of importance to plant growth (an interesting exception being nitric nitrogen), but the amount of adsorbing surface exposed by the soil particles is relatively enormous as compared with the volume of water in the soil solution. Hence, speaking generally, it would be necessary to add a great deal of a soluble salt, far more than is practicable in general farming operations, to produce a change in the concentration of the soil solution sufficient to be detected in any other way than by the response of a growing plant. It may be noted, in passing, that the growing plant

is a far more sensitive instrument than any of man's devising.

The importance of this subject justifies a repetition of the above argument in a somewhat different form. Consider again, for convenience's sake, the concrete case of soluble potassium in a soil at optimum water content. As the soil dries out there is a concentration of potassium in the remaining solution, which might easily reach a point where it would be actually toxic to plants, were it not for the fact that the relatively great adsorbing surface of the soil must simultaneously increase concentration also with respect to the potassium, so that the actual change in the liquid phase is quite small and is gradual. But that these small gradual changes are taking place continuously is beyond doubt.

Since Liebig's time, another class of substances has come to be well recognized, namely, solid solutions; that is, homogeneous mixtures in the solid state which can not be separated by mechanical means and which, unlike definite compounds, may vary gradually in composition with a corresponding gradual change in properties. Solid solutions are probably of great significance in soil phenomena. For instance, it is probable that most of the phosphoric acid in the soil is in the form of solid solutions. If a solid solution be in contact with a liquid solution and they both contain a common constituent, then every variation of the concentration of the common constituent in the one solution necessitates a corresponding variation in the concentration of the other solution. In general, and certainly with such cases as can reasonably be expected to exist in soils, a very considerable variation in the concentration of the solid solution corresponds to a much smaller variation in the liquid solution. Thus the addition of a large amount of a soluble phosphate to a soil might temporarily produce a considerable increase in the concentration of the soil solution, but only temporarily, for very quickly most of the phosphoric acid would be absorbed by the relatively large mass of ferruginous material present in soils to form a solid solution; *i.e.*, basic ferric phosphate.

Thus, as regards the composition of the soil solution, the concentration of the several constituents and components is continually changing, and the phenomena are dynamic, for what has been presented here holds for organic as well as inorganic substances.

To trace in a similar way the phenomena of the soil atmosphere and the living organisms within the soil would necessitate going far beyond the reasonable bounds of a lecture. Suffice it to call attention here to the quite obvious fact that all the phenomena these subjects call to mind are of a dynamic character.

SOIL MANAGEMENT.

Consider now the fundamental problem of soil management; namely, the production of a crop (C). This depends on certain factors which are variables—upon:

(R) The rainfall. Not only as to amount, but as to distribution.

(S) The sunlight. Again, with regard to distribution as well as amount.

(P) The plant itself. For there is great variation between a potato, let us say, and a wheat plant or a cherry tree.

(p) The physical properties of the soil.

(c) The chemical properties of the soil. Not alone as to the mineral nutrients or so-called "plant foods," but of all the chemical processes, organic as well as inorganic, taking place, and especially, perhaps, the balance between oxidation and reduction processes.

(b) The biological properties of the soil, including not only the now familiar bacterial flora, but enzymes and moulds which are common, if not necessary, accompaniments of cultivated crops; the adaptability of the soil as a habitat for earthworms, insects, etc.

Besides these so-called natural factors, and perhaps others which we dimly suspect without being able to definitely formulate, there are three artificial factors, the products of man's ingenuity, namely:

(T) Tillage operations;

(R) Crop rotations; and

(F) Fertilizers.

Gathering these factors together in mathematical form, for convenience's sake, they may be written:

$$C = \int (R, S, P, p, c, b, \ldots \ldots F, T, R).$$

For the solving of such a function there are two possibilities:

First, if the variables are independent of one another, they can all be made constant but one. This is the assumption very generally made in the past by experimenters with pots and plots; and the rigid adherents to the plant-food theory of fertilizers have implicitly assumed further that the function is linear (that is, the simplest possible), which it certainly is not. Fertilizer responses by crops should be strictly additive, which they are not.

Second, if the variables are dependent (that is, mutually affect one another), then it will be necessary to determine these interrelations before one can substitute their equivalents and solve the function, even qualitatively. That the variables are all dependent will be obvious on even a cursory survey of existing knowledge. Consider, for example, the plant factor, P. It is obviously affected by the amount and distribution of the rainfall and of sunshine. Root penetration is affected by the tilth and the physical factors. Growth is certainly affected by the balance between bacterial flora, the types of moulds developed in the soil, and the balance between oxidation and reduction processes, and certainly by the composition of the soil solution and its movement in the soil. These factors are in turn all affected by the tillage, the crop rotation, and the fertilizers. A mineral salt added to the soil probably produces effects larger in degree and as important in kind on the crumbing and decrumbing of soils and the other physical factors as on the chemical properties. It directly or indirectly influences the development of the various types of bacteria and other organisms. It influences the aëration, the movements and distribution of the soil solution, root penetration, and root absorptions.

It is a recognition of the interdependence of these variables that marks the first important step towards a really scientific development of the important art of soil management or crop production. Meanwhile it may not be amiss to point out the practical usefulness of this formulation. Consider a case from actual experience: a farmer who planted a rather heavy clay loam to wheat, and, being advised that his soil was "deficient" in potash, applied a generous amount of wood ashes for their

content of potassium carbonate. Undoubtedly he increased the amount of "plant food" thereby, but the potassium carbonate, being decidedly alkaline, puddled his heavy soil, impeded root penetration, retarded the movement of moisture, thus cut down absorption of solar radiation, and made a cold soil. Aëration being poor, there was an abnormal development of unaërobic bacteria, and, in fine, the crop was poor, as might have been anticipated. If he had used potassium sulphate, on the other hand, he might have anticipated a greater selective absorption of potassium than of sulphion by both soil and plant, and a slight acidifying of the soil solution. If not too great, this would have stimulated root development, would have induced crumbing and better tilth, and possibly bad effects on plant and biological factors could be obviated by a light dressing of lime, which, unlike other alkalies, has a flocculating effect. The lime would have been even more desirable if he had used potassium chloride.

Again, take the case of tomatoes on a light, sandy loam, where it was proposed to use heavy applications of sodium nitrate. There is a very marked selective adsorption by soils in the case of this salt, sodium being strongly adsorbed and nitric acid very little adsorbed. But, on the other hand, nitric nitrogen is very quickly absorbed by growing plants, which give a very marked response in increased leaf development. On a sandy loam, therefore, the tomatoes would be expected to make a very rapid growth, with the aërial portion of the plant out of proportion to the roots. A short spell of hot weather might then produce disastrous wilting. The accumulation of the free alkali sodium as carbonate and bicarbonate near the root crown might cause serious injury to the bark, and in an actual case there was a serious baking of the surface soil, induced partly, no doubt, by the puddling action of the too strongly-alkaline residue. Without following the case further, it will be seen that a chance of a successful crop is not alluring. A similar analysis for ammonium sulphate also indicates a doubtful success. It would have been better to have depended largely upon an organic nitrogen carrier, with good tillage to induce proper bacterial activities, and to have supplemented this by occasional light applications of sodium nitrate or ammonium sulphate as the condition of the growing crop might indicate.

Returning to theoretical considerations, it would be noted

that the equation is not one of state, but an equation of motion, since, from what has been pointed out already, every one of the natural factors is continually in a process of change. The problems of soil management are therefore essentially dynamic. Moreover, when it is considered that the soil is made up of a large number of components, and that the properties of the soil are not merely the sum of the properties of the components, but the summation of these properties as they mutually affect and modify each other, it becomes evident that a particular soil is a system pretty high in the scale of complexity, and that the differences between soils become of relatively more importance than the similarities and common properties. In other words, soils must be considered as individuals. And nothing that is done to one soil can be expected to make it the same as another soil, not even in crop-producing powers, except by a meaningless accident.

The time has now arrived when it must be recognized that the problems of soil fertility are no longer problems merely of soil composition or merely of a supply of plant food. The great fundamental questions now are, not what things are in a soil, but, What are the processes—physical, chemical, and biological—taking place continually in the soil? What are their magnitudes, and what are the rates of change? How do they affect one another? What are the *differences* between individual soils that are the expression of the resultants of these interdependent processes?

To-day we have partial answers to these questions. To-morrow the answers will be fuller and more nearly complete. But they will inevitably raise new questions. Meanwhile the art of soil management will develop and improve as our knowledge of the factors involved gives us a more intelligent control of them. It is ridiculous to be satisfied with a yield of fifteen or even fifty bushels of wheat to the acre when, under controlled conditions in a greenhouse, wheat has been raised to the extent of upwards of 160 bushels to the acre.

But it is not the purpose of this lecture to speculate on the future possibilities of agriculture, no more than it is to give a complete review of existing knowledge regarding soil fertility. Only a small number of the "high points" can be noted. But enough of these have been touched, it is hoped, to demonstrate that there has been a steady progress from van Helmont's time

to the present; that, as Liebig's work was a necessary and logical development of the work of his predecessors, although at the time it appeared startling and was provocative of bitter contentions, so the development of the dynamic viewpoint as sketched here is but a logical and necessary consequence of the work since Liebig. Before Liebig many mistakes were made, but some truth was found. Liebig made many more mistakes, but he added much to the store of truth. Since then, doubtless, much that has been done and said will prove mistaken or of little worth; but out of it all we can confidently believe that the store of true knowledge has greatly grown and that our vision is wider and more trustworthy.

The increase of human knowledge in every field of scientific inquiry appears, at close range, to go forward *per saltem,* and it is sometimes hard for the individual scientist to take the leap. But, looked at from a proper perspective, there appears to be a smooth and regular progression. Thus the recognition of the dynamic viewpoint of soil fertility merely marks a convenient point on the curve representing the steady growth of knowledge in a field of inquiry of fundamental importance to the happiness of the human race.

Submarine Oil Pipe-lines. P. C. A. STEWART. (*Journal of the Royal Society of Arts,* vol. lxiv, No. 3287, November 19, 1915.)—Owing to the unfavorable nature of the comparatively shallow water close in to the coast, the Mexican Eagle Oil Company originated the idea of laying submarine pipe-lines to points where the largest tankers could be conveniently moored for loading purposes at any state of the tide and weather. They have three deep-sea loading berths at Tuxpam Bar with duplicate pipe-lines to each berth; the Penn Mexican Fuel Company also has two loading berths equipped with pipe-lines in duplicate. The lines terminate in 43 feet of water, which is below wave-action, and at the point where the pipe ends 120 feet of armored flexible hose is attached. The free end of the hose is closed by a blank flange and allowed to lie on the sea-bottom when not in use, its position being marked by a buoy with a chain sufficiently strong to lift it.

The rise and fall of the tide is approximately two feet, so that the depth of water, 43 feet, is sufficient for the largest tank steamers to load at any time. Tankers of 15,000 tons dead weight, drawing 28 feet, are regularly loaded.

Electric Heating and Cooking. P. W. GUMAER. (*Scientific American,* vol. cxiii, No. 23, December 4, 1915.)—A new type of heating unit has recently been devised for electric-heating devices. The high-resistance wire through which the electric current flows is enclosed in a steel sheath, and insulated therefrom by a material which will withstand excessively high temperatures without deterioration. The core wire and powdered insulation are inserted in the sheath when the three are large in diameter. They are then rolled and swaged to the proper size. By an ingenious arrangement the ends or terminals of the unit are left large in diameter. This facilitates the attachment of terminal connections and permits the terminal to operate at a low temperature. The outside metal sheath protects the core wire from oxidation when operated at high temperatures, as air can not penetrate through the sheath and as the core wire is large in cross-section and comparatively cool where it is exposed to the air.

This type of heating unit lends itself readily to the construction of a hot-plate or stove which is practically ideal. The sheathed wire is arranged in a flat coil and molten iron is cast around it. The result is a heating unit which is rugged and durable as an old-fashioned stove-lid. Good thermal contact is obtained from the resistance wire through the sheath to the cast iron. The low thermal resistance path for the heat and a heat-insulating pad beneath the unit secure an especially high efficiency.

Modern Electric Elevators and Elevator Problems. D. LINDQUIST. (*Proceedings American Society of Mechanical Engineers,* New York, December 7th to 10th, 1915.)—The elevator art has gone through quite a number of more or less radical changes in the last fifteen years. These changes have been partly due to developments in building construction, making it possible and practicable to erect high structures. Elevators may be classified according to the driving power employed: steam-driven, hydraulic, and electric. The first class is now practically obsolete. Hydraulic elevators may be divided into several groups, depending upon the different methods by which the hydraulic power is applied to the car. The principal and well-known types in common use are the horizontal hydraulic (rope-geared), the vertical hydraulic (rope-geared), and the plunger hydraulic (direct-connected). These were introduced in the order named for high speed in comparatively high buildings. The plunger type practically superseded other types of hydraulic elevators during the period of 1904 to 1907. Now, in turn, the plunger has been almost entirely superseded by the gearless " one to one " type of electric elevator. The electric achievement in the design of a motor capable of operating efficiently at 60 revolutions per minute and less is responsible for this radical design of elevator drive. Incidentally this design affords unusual opportunities for interesting and very efficient methods of braking and control.

A 32-ELEMENT HARMONIC SYNTHESIZER.*

BY

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HARMONIC ANALYSIS AND SYNTHESIS.

THE harmonic method of analysis based upon Fourier's Theorem, first published in "La Théorie Analytique de la Chaleur" (Paris, 1822),[1] is of the greatest value in the investigation of many curves, and especially of periodic curves which represent wave motion. The method has been successfully applied in many branches of science, such as acoustics, electricity, magnetism, heat, optics, astronomy, mathematics, tidal phenomena, meteorology, seismology, naval architecture, statistics, and mechanical engineering. This theorem may be stated as follows: If any curve be given, having a wave-length l, the same curve can always be reproduced, and in one particular way only, by compounding simple harmonic curves of suitable amplitudes and phases, in general infinite number, having the same axis, and having wave-lengths of l, $\frac{1}{2}l$, $\frac{1}{3}l$, and successive aliquot parts of l. The given curve may have any arbitrary form whatever, including any number of straight portions, provided that the ordinate of the curve is always finite and that the projection on the axis of a point describing the curve moves always in the same direction. The significance of this theorem as applied to particular curves is explained and graphically illustrated in other parts of this paper.

Fourier gave a complete method of analysis by numerical calculation for determining the exact size and position of the component simple curves required to represent the given curve. The calculation, which is very laborious, involves the evaluation of a large number of "definite integrals," each of which is of the nature of an area. It has been found possible to measure the areas pertaining to a given curve (that is, to evaluate the definite integrals involved in the Fourier equation) by tracing the curve with mechanical integrators known as *planimeters*. A complete apparatus arranged for the purpose of mechanically deriving the Fourier equation of a curve is called a *harmonic analyzer*.

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* Communicated by the Author.

The first harmonic analyzer was devised by Lord Kelvin, about 1872, in the development of a method for predicting the tides. The rising and falling of the tides at any locality, having been observed for a period of time, as for a year or more, is represented by a curve. Such a curve is the resultant of a number of periodic factors and is, therefore, suitable for harmonic analysis. The periods are determined by theory, but the amplitudes and phases are found by analyzing the observed curve. The periods of the tidal components are not related to one another in simple ratios (that is, they are inharmonic in time), but the method of analysis is, nevertheless, applicable, as each tidal curve is compounded of separate curves, each of which is a simple harmonic curve. Lord Kelvin's analyzer[2] is based upon the rolling sphere-and-cylinder integrator devised by his brother, James Thomson.[3] The original instrument is now in the museum at South Kensington, London. Numerous other analyzers, suitable for general or special purposes and using various types of integrators, have been devised, that of Henrici being perhaps the most precise and convenient.[4]

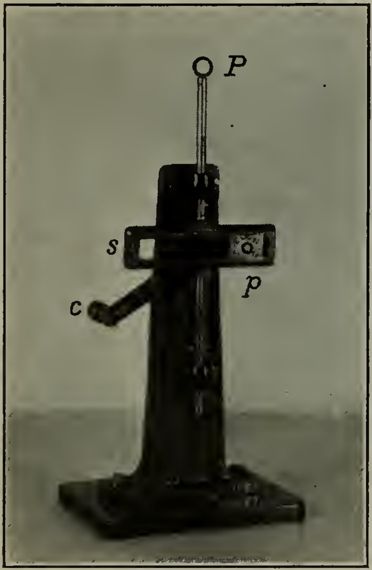
The observed tidal curve, for a given station, having been resolved into its simple elements, the prediction of the tides requires the recompounding of these elements under the given conditions relating to the future date. If the resultant is represented by a curve, the high tides and the low tides are directly shown and can be measured and the time of occurrence can be specified. The compounding of the elements can be done numerically in some instances, and can always be accomplished graphically. As is the case in analysis, these operations are laborious, and Lord Kelvin and others have constructed machines for drawing the composite curves; such machines are called *harmonic synthesizers*.

Lord Kelvin's harmonic synthesizer is based upon an old mechanical movement (Fig. 1), known as the pin-and-slot device. When the crank c is turned with uniform angular speed, the pin p causes the frame s and all attached parts, as the point P, to move up and down with *simple harmonic motion*.

The usual starting point in describing such motion is the middle position of P when it is about to move upward; that is, when the crank is horizontal with the pin p at the extreme right and about to turn counterclockwise. One *complete vibration* is

produced when the point P moves from its mid-position to the upper position, to the lower extreme, and back to mid-position; that is, when the crank makes one complete revolution. The *frequency* is the number of complete vibrations, or revolutions of the crank, per second; the *period* is the time required for one complete vibration. The *phase* at any instant is the fraction of a period which has elapsed since the point last passed through the starting point, and is often expressed by the number of degrees which represents the position of the crank-pin as referred to its

FIG. 1.



Pin-and-slot device for producing simple harmonic motion.

initial position. The *amplitude* is the range in one direction or the other from the middle point of the motion of P; therefore, it is half the extreme range of the vibration, and it is measured by the length of the crank from the centre to the pin p.

The first suggestion for compounding several simple harmonic motions so produced was made by Rev. F. Bashforth, in 1845,[5] and Lord Kelvin made the first machine, known as a *tide predictor,* under the auspices of the British Association for the Advancement of Science, in 1873.[6] The principles involved are

shown by the apparatus represented in Fig. 2. A cord *c*, fixed at one end, passes around several pulleys, and at the other end is attached to a pencil *p*, which makes a trace on a moving chart. The pulley *a* is attached to a pin-and-slot device, which moves up and down with a simple harmonic motion. The cord transmits this motion to the pencil, doubled in amount. If the chart moves horizontally with a uniform motion, the trace is a simple harmonic curve; this curve, also called a *sine curve*, represents the simplest possible wave motion. The frequency of the motion, or the number of waves per second, depends upon the rapidity with which the crank-pin is rotated, and the amplitude of the wave depends upon the distance of the pin from the centre of its crank; the *wave-length* of the curve depends upon the speed with which the chart moves. If another pulley *b* is attached to a second pin-and-slot device rotating twice as fast as the first, it will give the pencil a simple harmonic motion of twice the frequency of the first. It is evident from the illustration that if the two devices operate simultaneously the cord will transmit to the pencil a composite motion which is at all times the algebraic sum of the two separate motions, and that the trace will be the synthetic curve of the two simple harmonic curves. The scheme may be extended to include any number of simple harmonic motions having any specified frequencies, amplitudes, and phases.

A most remarkable and elaborate tide-predicting machine with 38 elements, based upon these principles, has been constructed by the United States Coast and Geodetic Survey. A complete description of this machine and brief descriptions of all other tide predictors, beginning with that of Lord Kelvin, are given in "Special Publication No. 32" of the United States Coast and Geodetic Survey.[7]

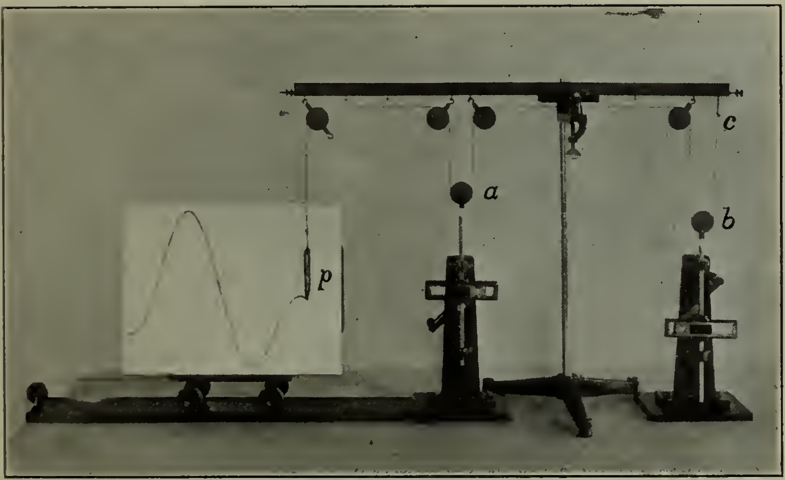
Other methods of harmonic synthesis have been devised. Professor A. A. Michelson has made a machine with 80 elements in which the harmonic components are represented by the tensions of springs; this instrument may also be used as an analyzer.[8] Machines employing gear wheels have been constructed, but these are usually limited to a few elements.[9]

A 32-ELEMENT SYNTHESIZER.

For some time the writer has been engaged in an investigation of photographic records of sounds by the method of harmonic analysis.[10] The analyses have been made with a Henrici har-

monic analyzer. As provided by its maker, this instrument is limited to the determination of ten components of the curves. By an addition to the analyzer, its operation has been extended to include thirty components. The nature of this alteration will be described later in this journal. Thousands of curves containing from ten to thirty components have been thus analyzed. The correctness and sufficiency of these analyses can best be proved by synthetically combining the elements given by the analysis. The synthesis should exactly reproduce the original curve. For this purpose, a harmonic synthesizer of ten elements, based upon the

FIG. 2.

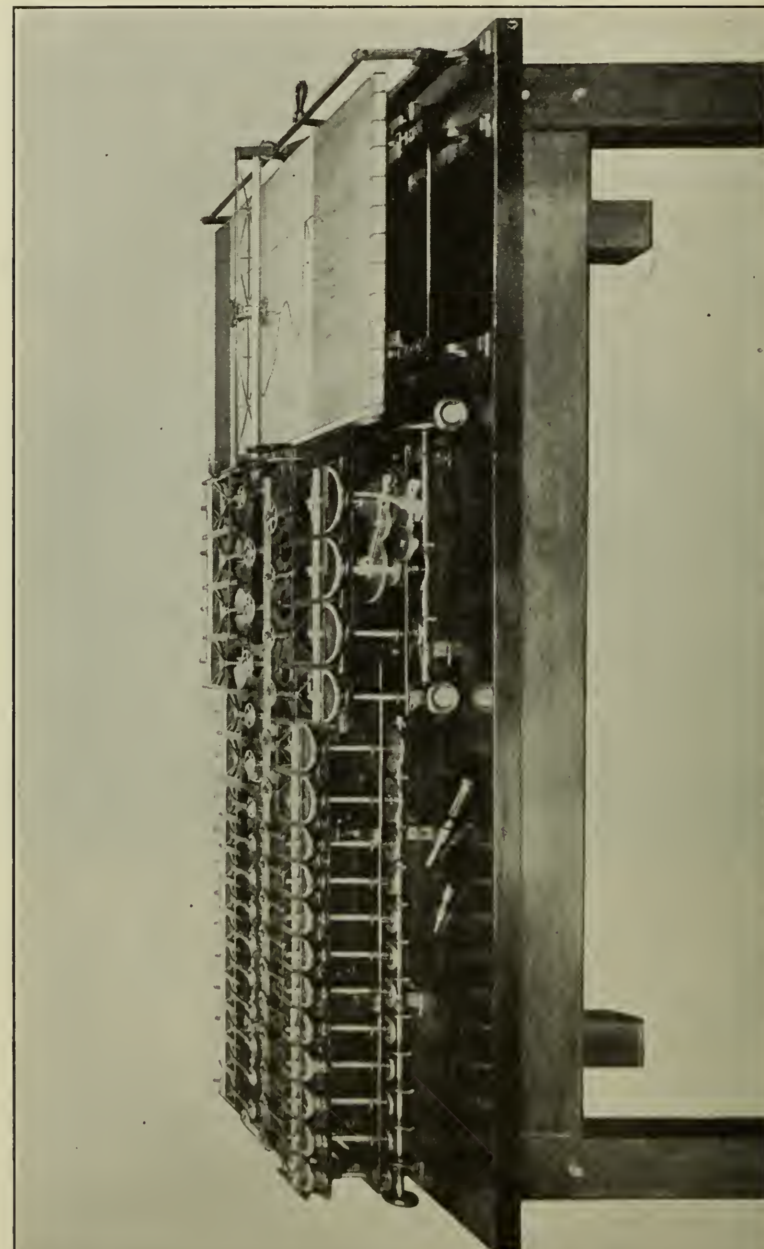


Apparatus for illustrating the principles of the harmonic synthesizer.

pin-and-slot device was constructed in 1910. This instrument was soon found inadequate for the study of musical sounds, and was dismounted in 1914 upon the completion of the 32-element synthesizer, shown in Fig. 3.

This instrument, which is perhaps the most complete and convenient harmonic synthesizer of general application yet constructed, was designed and built in the laboratory and instrument shop of the Department of Physics of Case School of Applied Science. The Henrici analyzer requires that all curves for analysis shall be drawn to the wave-length of exactly 400 millimetres (about 16 inches), and the synthesizer has been constructed to

FIG. 3.



Harmonic synthesizer for graphically compounding 32 simple curves.

reproduce curves upon this large scale. It is also arranged for other wave-lengths.

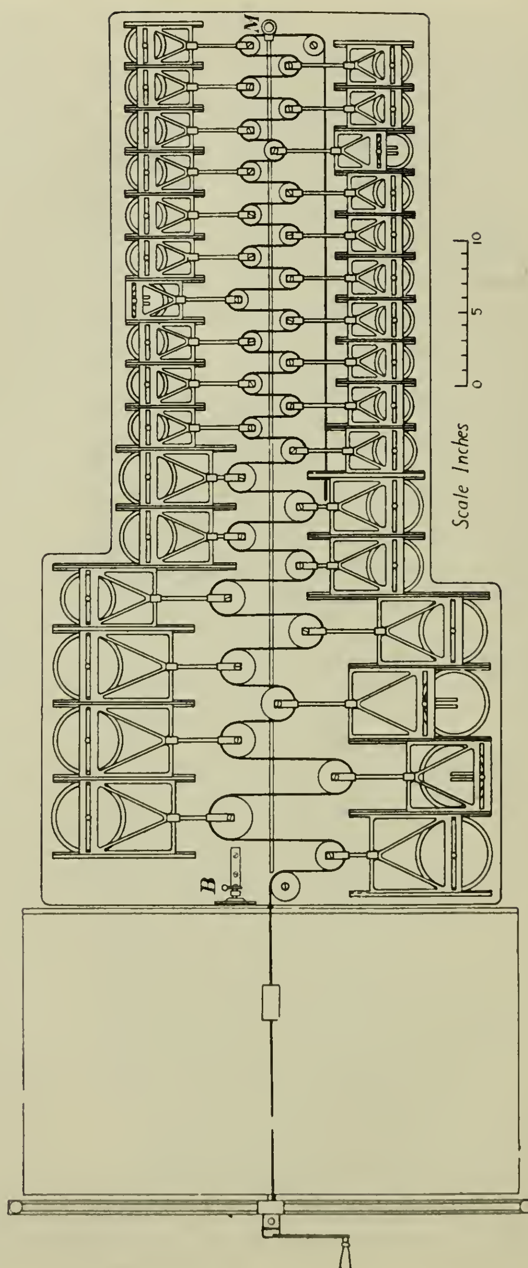
With the larger wave-lengths it may happen that one or two components of a curve will have amplitudes of 200 millimetres (8 inches) or more. Usually only components of lower order are large, and the scheme adopted for this machine provides for amplitudes up to 340 millimetres (13 inches) for any one of the first six components, the other five amplitudes not exceeding 100 millimetres each at the same time. The diameter of each disk of the pin-and-slot device must be a little greater than the maximum amplitude of the corresponding component. To have provided for amplitudes of 300 millimetres, or even of 200 millimetres, for the first six components, would have made the completed machine large and cumbersome. Instead of six disks 300 millimetres in diameter (12 inches) for the first six elements, together with correspondingly large sliders and long strokes for the chain pulleys, six disks about 100 millimetres (4 inches) in diameter were used, and two additional disks 112 millimetres in diameter are provided, one or both of which can be made to supplement any one of the six disks. Since the disks are arranged on opposite sides of the main frame, in pairs, this saves more than 24 inches in the length of the machine and more than 32 inches in the width.

The dimensions chosen for the various parts, as described later, require a base for the instrument which measures 38 by 87 inches. This base is in the form of a table built especially for the purpose; the supporting parts are of oak, held in shape by stay-bolts, while the top is of cast iron in one piece, weighing about 500 pounds. There are several crossed ribs, about three inches deep, cast on the under side, which stiffen the plate. The machine rests on 24 bosses, the upper surfaces of which have been machined to one plane, while the plate was supported on three points—two at the corners on one end and one at the middle of the opposite edge. The plate in its final position as the top of the table is supported on the same three points only.

THE INTEGRATING ELEMENTS.

After the number and sizes of the elements have been determined, the next consideration is the convenient setting of the amplitudes and phases. This is especially important where hun-

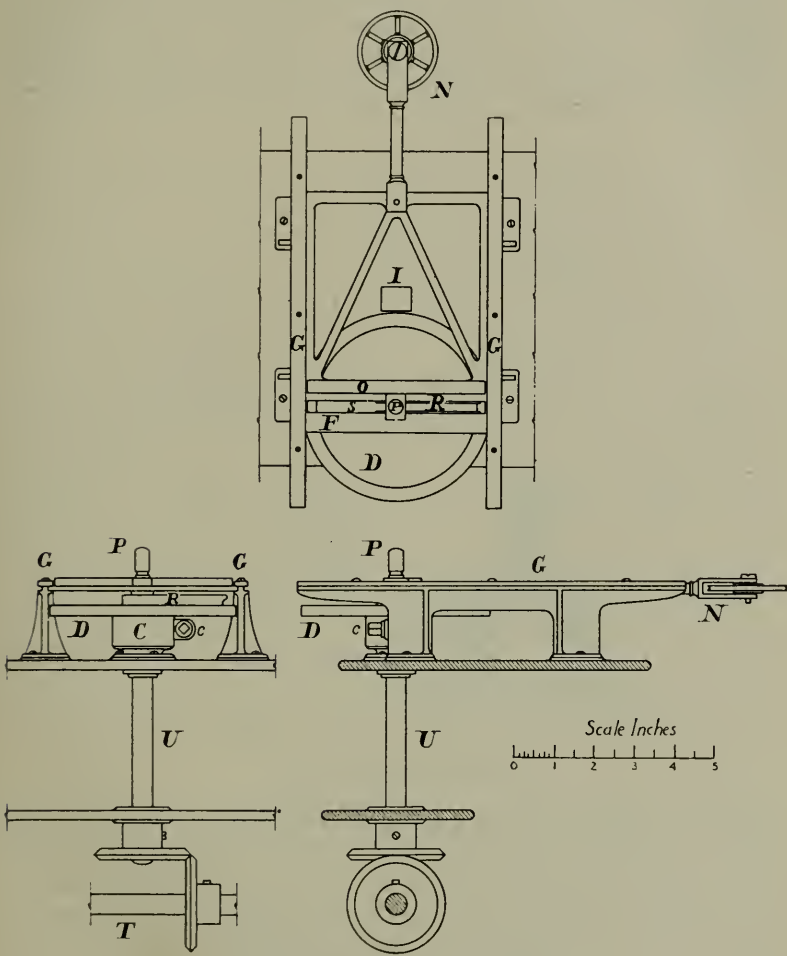
Fig. 4.



Top plan of the 32 integrating elements of the synthesizer.

dreds of curves are to be synthesized in succession. The disks are arranged horizontally along the outer edges of the main frame, as shown in Figs. 3 and 4, while the drawing-board which

FIG. 5.

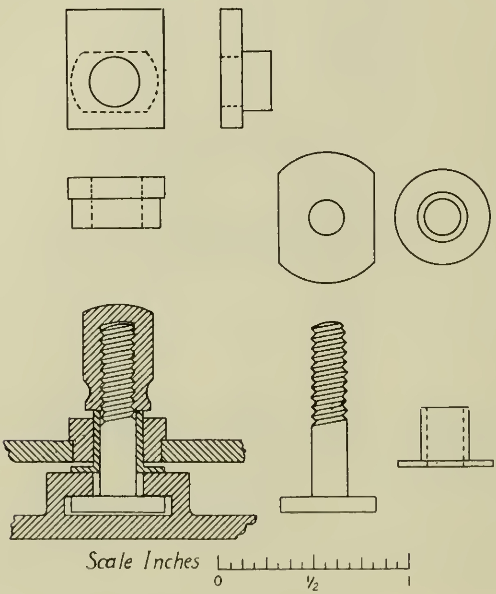


Details of one pin-and-slot element.

carries the chart on which the curve is to be traced is placed at the end near the larger elements. Before explaining the plan of the machine, the details of a single pin-and-slot element will be described.

The vertical shaft *D*, Fig. 5, is permanently geared to the driving shaft *T*. Attached to the upper end of the shaft is a cup-clutch *C* with a clamping screw *c*. The disk *D* has a hub which accurately fits the cup-clutch. By loosening the screw *c*, the disk can be turned to have any angular relation to the shaft and gears. The upper edge of the disk has a circle of white celluloid with graduations in degrees. A fixed index *I* shows the angular position of the disk or indicates the "phase" of the

FIG. 6.



Details of the pin and clamp.

element. Eight equidistant holes are drilled in the edge of each disk for receiving a capstan pin to assist in setting the phases. On the disk is a radial slot *R* in which slides the pin *P*. By means of a clamping device, shown in detail in Fig. 6, the pin can be held in any position from the centre of the disk to the outer edge.

The pin fits a hole in the centre of a small rectangular block of steel which slides in the slot *S* of the frame *F*. The frame *F* is movable to and fro between the parallel guides *G*. The sliding block in the slots carries a celluloid index which indicates the eccentricity of the pin on a graduated scale *O* of celluloid. A

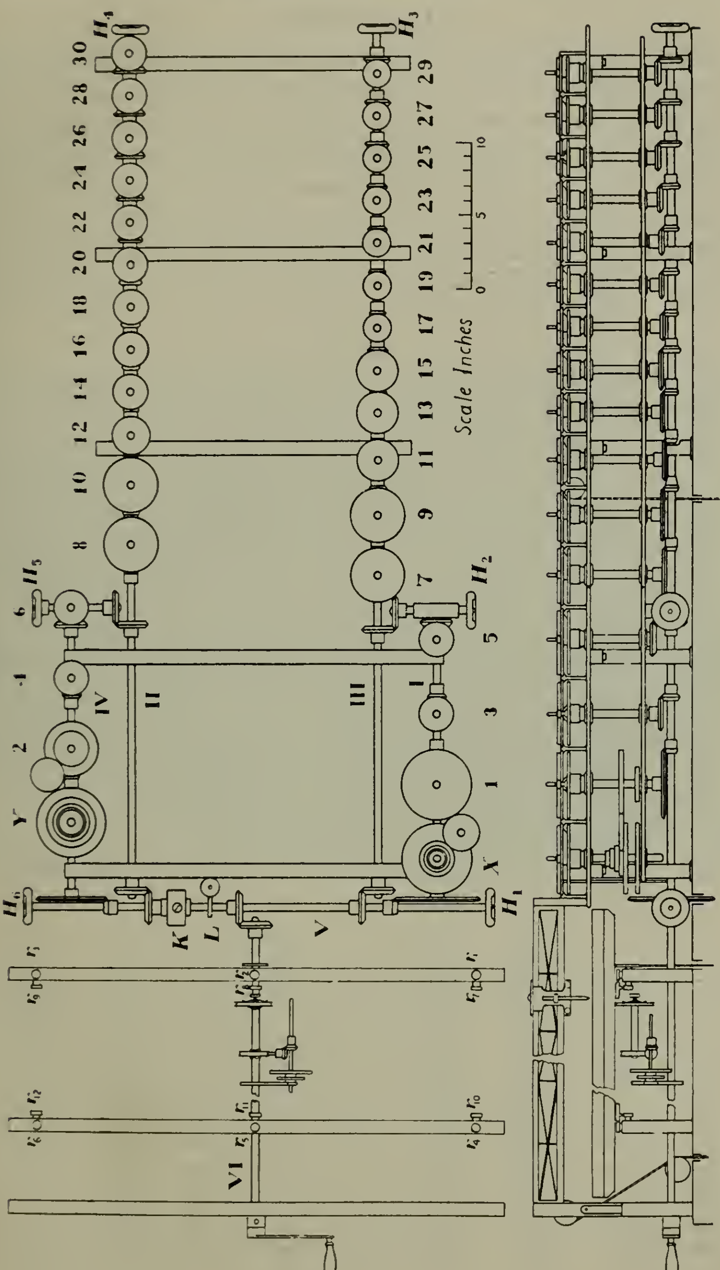
pulley N is attached to the frame by a connecting rod. When the pin P is at the centre of the disk, the rotation of the disk produces no motion in the frame, but when the pin is set to one side of the centre the pin moves in a circle and, sliding back and forth in the slot of the frame, causes the frame and the pulley to move with simple harmonic motion, having an amplitude equal to the eccentricity of the pin. This simple harmonic motion, doubled in amount, is transmitted by a chain passing around the pulley to the pen. As it is the motion of the pen that is recorded, the graduated scale O is divided into half-millimetre spaces which are numbered as millimetres; thus the desired amplitude is set directly on the scale. The pin through the centre of the pulley N runs in a rectilinear guide, retaining the pulley in its proper position.

The 32 elements of the machine are arranged on a cast-iron bed-plate, as shown in Fig. 4. A flexible chain of the kind known as "chronometer fusee chain," 1/16 by 1/32 inch, is threaded around the pulleys. One end of the chain goes to the pen carriage above the drawing-board and over other pulleys to a weight of 300 grammes, which hangs below the table and serves to keep the chain under constant tension. The other end of the chain passes around two supplementary pulleys to another weight of 300 grammes which also hangs below the table. The chain is thus balanced and free to move through the entire series of 32 pulleys attached to the elements and over five other pulleys. These 37 pulleys are all made of aluminum and have ball-bearings. When the chain moves, it carries with it only the pen carriage and the two weights attached to its ends. The pen carriage rolls on ball-bearing wheels. The friction is so small that a pull of 120 grammes (about 4 ounces) is sufficient to move the chain and pen carriage. The small inertia of the wheels and the freedom from friction are important in allowing a small component movement of the elements of high order to be transmitted without loss through nearly the whole series of pulleys to the pen carriage. The design of the apparatus is such that each pulley, when in one extreme position, comes as close as possible to the centre line of the instrument; this gives the shortest possible length of chain, reducing the sag and stretch to a minimum. The chain is actually 27 feet long. Such a balanced chain is very convenient in setting the instrument, but the upper part of the chain must be held stationary in order that the various component motions of the

several pulleys may all be added and transmitted to the pen when a curve is being drawn. For this purpose a chain clamp *M*, Fig. 4, is provided; the clamp holds the chain to a rigid bar which passes under the various cross chains throughout the length of the machine. Many curves are drawn which have less than thirty components; to avoid the necessity of setting the higher elements, perhaps twenty or more in number, to zero for such curves, the chain clamp may be placed at any point where the chain crosses the centre bar. Then only those components which are between the clamp and the pen produce any effect on the motion of the pen; the components above the clamp may move in any degree, and they cause motion only in the upper part of the chain, which hangs freely with a weight on the end. If one wishes to draw a curve using only the upper components, as, for instance, components 29 and 30, the chain may be clamped just below element 29, and the upper end of the chain, instead of being attached to the weight below the table, is carried directly to the pen. Thus the threading of the long chain through the thirty pulleys which are not required is avoided. This adds to the delicacy of action. It is possible to draw a sine curve in this manner the actual amplitude of which is less than a hundredth of an inch, while so small a movement would hardly be passed around all the pulleys.

Most of the elements as shown in Fig. 4 are in medium or zero position, with the pins in the centres of the disks and with the radial slots of the disks parallel to the slots in the frame. So long as the pins remain in the central positions, rotation of the disks produces no motion of the frames and pulleys; when the pins are eccentric and the disks are rotated, the frames and pulleys are moved. The pins for four elements are shown at the extreme ends of the radial slots. The second disk in the lower row has been turned downward 90 degrees, which pulls the pen carriage upward on the drawing-board; one of the elements in the upper row is shown in a similar position. The third elements from either end of the lower row are shown with the disks rotated to the 270-degree position, which allows the pen to move downward over the board. As shown in the figure, the positions of the four displaced elements are such as to neutralize each other in pairs, and thus there will be no resultant displacement of the pen in this particular instance.

FIG. 7.



Plan of the gear system of the synthesizer.

THE GEAR SYSTEM.

The turning of the handle must rotate all the vertical shafts continuously in such ratios that when the shaft for the first element has turned once, that for the second element shall turn twice and the others shall turn three, four, and so on, up to thirty times. The two supplementary elements X and Y must be rotated one half turn, one turn, two, three, four, five, and six turns, while number 1 turns once. The system also includes the phase dial B, Fig. 4 and Fig. 8, which turns once, and the drawing-board, which must move at right angles to the line of motion of the pen, at a uniform speed, moving the distance of one wave-length while element 1 turns once. The dimensions chosen for the amplitudes and the sizes of the sliding frames require that for compactness no gear for an element shall exceed five inches in diameter. Gears of 32 diametral pitch were chosen as giving convenient numbers of teeth for the required ratios. The vertical shafts are driven by four parallel horizontal shafts, *I, II, III,* and *IV,* Fig. 7. The four shafts are driven by one transverse shaft *V,* which in turn is driven by the handle shaft *VI*. The handle turns 30 times for one wave; shafts *V, II,* and *III* also turn 30 times, while *I* turns five times and *IV* turns six times per wave-length.

The following table shows the turns per wave-length (30 turns of the handle) for the driving shafts and for the disks, and also the number of teeth in the pairs of bevel gears for 30 elements:

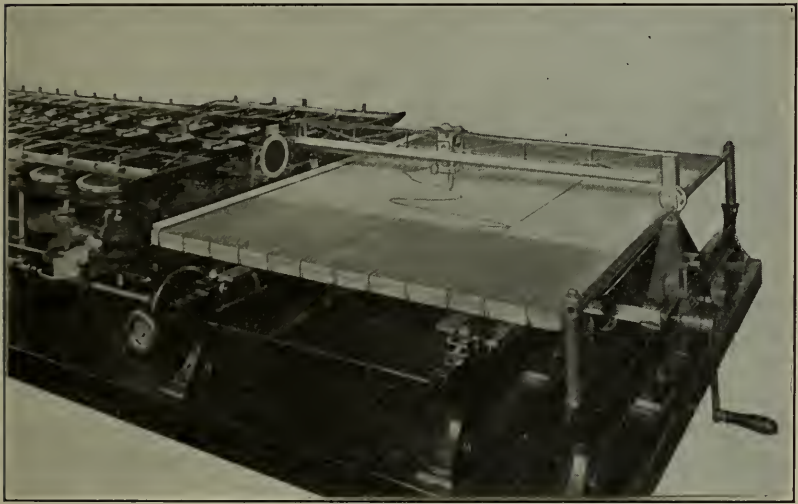
Turns for One Wave-length, or for 30 Turns of the Handle.

Disk	Shaft	Driver	Driven	Disk	Shaft	Driver	Driven
1	5	32	160	2	6	40	120
3	5	45	75	4	6	50	75
5	5	75	75	6	6	75	75
7	30	28	120	8	30	32	120
9	30	36	120	10	30	40	120
11	30	33	90	12	30	36	90
13	30	39	90	14	30	35	75
15	30	45	90	16	30	40	75
17	30	34	60	18	30	45	75
19	30	38	60	20	30	50	75
21	30	42	60	22	30	55	75
23	30	46	60	24	30	60	75
25	30	50	60	26	30	65	75
27	30	54	60	28	30	70	75
29	30	58	60	30	30	75	75

In certain kinds of work, the odd terms only in the Fourier series are required to represent a curve. In drawing such curves it is convenient to have only the odd-numbered elements of the synthesizer at work: for this purpose, a clutch *K*, Fig. 7, is provided in the transverse driving shaft *V* so that the shafts *II* and *IV* may be disconnected.

A pair of right-angle spiral gears *L*, Fig. 7, are connected to shaft *V* and, by means of a worm-gear of 30 teeth, turns the phase dial shown at the left of drawing-board, Fig. 8, and at

FIG. 8.



The drawing-board of the synthesizer.

B, Fig. 4. This dial indicates at all times the phase of the gear system as a unit independently of the phases of the separate elements, which are variable, and independent of the drawing-board, which is also adjustable. When setting up a curve, it is necessary that the gears be at zero phase, since only in this position are all the clamp screws of the cup-chucks *C*, Fig. 5, in position for the application of the clamp-wrench. This disk turns with the same speed as does the disk for the regular element No. 1, but it remains in a fixed relation to the gear system, while disk 1 may be set in various phases. The wave-length scale on the drawing-board also indicates phases, as is described later.

A pin stop is provided near the handle to hold the entire gear system fixed in zero position, while the several elements are being set in amplitude and phase. The handle itself is detachable by a bayonet catch. When verifying the settings of the amplitudes and phases of the elements, it is often convenient to be able to turn the gear system. For this purpose six hand-wheels, H_1, H_2, etc., Fig. 7, are connected to the driving shafts at points such that one can always easily reach one or two of the hand-wheels from any position near the machine.

A curious and interesting demonstration in statics is given by the system of gears, pulleys, and chains. The tension on the chain is 300 grammes, and, since each pulley is drawn by two portions of the chain, the pull on each of the 32 elements is 600 grammes (1⅓ pounds). When the disks are all at zero phase and the pins in the radial slots of the disks are all set as far as possible from the centres of the disks, they form 32 cranks, all tending to rotate the gear system one way. Actual trial shows that the pull on the crank handle necessary to lift the chain weight is about 23 pounds. At the same time that the chain pulls on the crank with 23 pounds pull, an additional weight of 4 ounces at one end of the chain will cause the chain to run freely through the entire series of pulleys and lift the weight on the other end of the chain. In actual practice, the crank pins are never all at the extreme eccentricity, and usually the phases of the cranks are so distributed that the crank actions on the gear system are largely neutralized. The pressure commonly required to turn the handle is about three pounds pull.

THE SUPPLEMENTARY ELEMENTS.

Thus 30 harmonic elements are provided, the amplitudes of the first five components being 100 millimetres each, and of the sixth, 90 millimetres. Two supplementary disks X and Y are provided, as already mentioned; disk X is driven by the vertical shaft of element 1 by means of a set of six change-gears with clutches; the disk Y is similarly driven by element 2. The gears for X permit it to be used for a component of frequency 1/2,—that is, one octave below the fundamental (such a component is required for some musical tones), or for components 1, 2, 3, 4, or 5; the gears for Y give it frequencies corresponding to the components 1, 2, 3, 4, 5, or 6. Thus there is a sub-octave element

with an amplitude of 120 millimetres, and any one of the elements 1, 2, 3, 4, or 5 may have an amplitude of 340 millimetres, the other four being limited to amplitudes of 100 millimetres each at the same time; or any two of the elements 1, 2, 3, 4 or 5 may have amplitudes of 220 millimetres each, the other three being then limited to 100 millimetres each; element 6 may have an amplitude of 210 millimetres, and any one of the first five elements may at the same time have an amplitude of 220 millimetres, the other four not exceeding 100 millimetres each. The amplitudes for components 7 to 10 may be as large as 80 millimetres each, component 11 may have an amplitude of 60 millimetres, and components from 12 to 30 may have amplitudes of 50 millimetres each. The disks X and Y can be made to give any desired inharmonic components by providing for each a single gear of the required number of teeth.

While the drawing-board is only 24 inches wide and the curves being studied in musical analysis are rarely as wide as this, yet much wider curves can be drawn. By using a wide sheet of paper, the curve is drawn to the limit of the board, then the paper is shifted sidewise and the pen chain is loosened in its clamp and the pen is shifted to the new position of the trace, the chain is again clamped, and the drawing is continued. Any one of the first five components may be drawn with a width of 27 inches, and the maximum sum of all the components would make a curve more than 14 feet wide.

THE DRAWING-BOARD.

The chart table, Fig. 8, is an ordinary draughtsman's drawing-board, 24 by 34 inches in size, which is mounted in a very firm manner and at the same time it moves accurately in a straight line and with great ease. It is held firmly against its guides by springs so that there is no lost motion. Guards are provided so that when one end of the board overhangs the supports, pressure, such as leaning on the board, can not tip it up against the pen nor out of its guides; stops are provided which limit its extreme motions. The board is entirely supported on ball-bearing rollers arranged as shown in Figs. 7 and 8. Attached to the under side of the board are two tracks of cast bronze, which are machined and polished where they run on the rollers. The important requirement is that as the board moves from one extreme to the

other, about 32 inches, the pen, being stationary, shall trace a straight line on the surface of the board. This is secured by having the three rollers r_1, r_2, and r_3, Fig. 7, in a line, and by having the straight edge of the track always in contact with two (or sometimes three) of the rollers. The three rollers r_4, r_5, and r_6 are pushed against the second track by springs in their mountings with a pressure of about ten pounds, and thus they keep the first track firmly against its guide rollers. The weight of the board is supported by six (or four) ball-bearing rollers, r_7 to r_{12}. A pull of about one ounce will move the board.

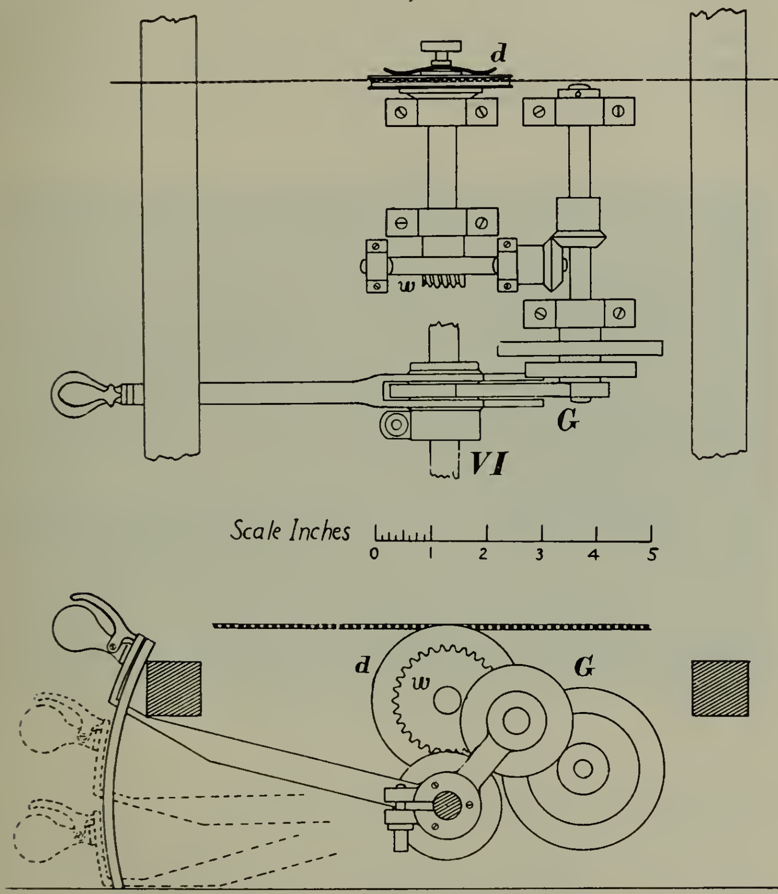
It is necessary that the board should travel exactly one wave-length when the handle is turned 30 times. The board is pulled by a chain, 1/10 inch wide and 1/20 inch thick, which winds around a metal drum *d*, Fig. 9, of such a size that one revolution moves the board 200 millimetres. The drum is turned by a worm-gear *w*, of 30 teeth, and the worm is driven from the handle shaft *VI*, Figs. 7 and 9, by means of the change-gear system *G*. The change gears are arranged for wave-lengths of 133.3 millimetres, 200 millimetres, and 400 millimetres. Any desired wave-length can be easily provided by substituting a gear of suitable size in the change-gear system, or by using a drum of proper diameter.

The drum around which the chain passes is held on its driving shaft by friction only. The friction is sufficient for moving the board properly from the driving gear. But it is possible, by exerting a little extra pressure on the board, to move it by the slipping of the drum on its friction holder, and so to set the board at any time to any phase position, independently of the handle and the gear system. This is a very great convenience, since after a curve has been traced by turning the handle forward, 30 turns for each wave-length, the board can be instantly pushed to the starting point for a new tracing instead of having to turn the handle backward the 30 or more turns. With any particular phase of the gear system, one can instantly bring any part of the drawing-board under the pen; it is, in effect, an endless drawing-board. The length of the curve drawn is usually one or two wave-lengths of about 16 inches each, but by shifting the paper on the board a curve of any length may be drawn.

On one edge of the drawing-board is a linear scale, Fig. 8, which shows the travel of the board in terms of the wave-length

of the curve being drawn, or it shows the phase of that part of the curve being traced. Since the drawing-board is held by friction only, this scale enables one to set the board in phase with the gear system as indicated by the dial adjacent to the scale.

FIG. 9.



Plan of gears for moving the drawing-board.

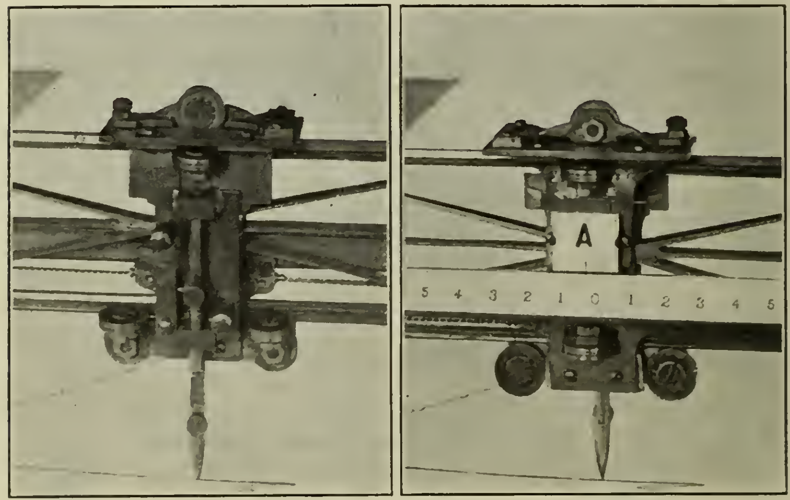
THE DRAWING PEN.

The pen track is a truss of cast bronze with six planed and polished ways. The pen carriage rolls on eight ball-bearing wheels. Five of these rollers are fixed to the carriage, while the other three hold the carriage firmly against the track by spring pressure exerted in three directions so that there is no lost motion.

While the carriage is held tightly to the track, yet it moves with great ease, a pull of about one ounce being sufficient to roll it along. Views of the two faces of the carriage are shown in Fig. 10.

The pen is an ordinary draughtsman's ruling pen, held in a steel rod which moves freely up and down, but without rotation. By means of a catch, the pen may be held above the paper; when in use, the pen presses with its own weight only on the paper, and remains perpendicular to the paper while tracing a curve.

FIG. 10.



Two views of the pen carriage.

This pen arrangement, which was adopted after trying several other types, is very satisfactory in its operation.

Attached to the pen track is a celluloid scale graduated in millimetres, with the zero at the centre. An index attached to the pen carriage, *A*, Fig. 10, indicates the displacement of the pen along the track; that is, it shows the amplitude of the curve at each instant.

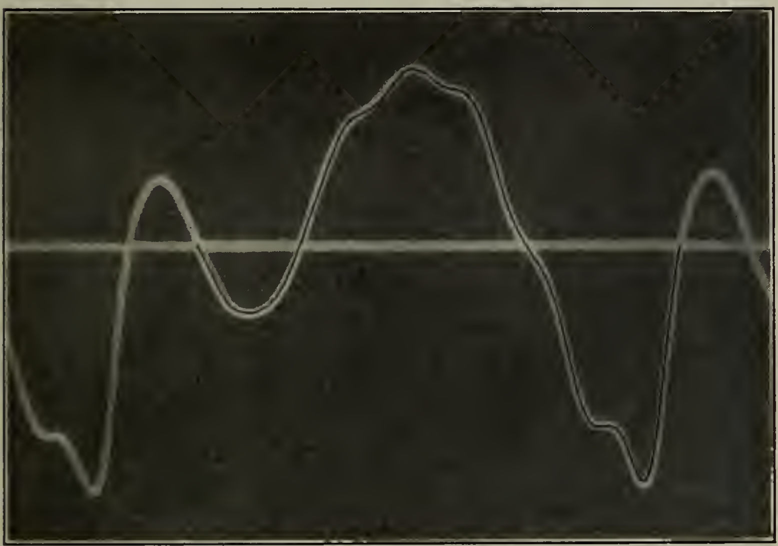
APPLICATIONS OF THE SYNTHESIZER.

In order to set the synthesizer for drawing a given curve, it is necessary to know the amplitude and the phase of each component; these quantities are the coefficients and epochs in the Fourier equation of the curve when the equation is given in the

form of a single series of sines or cosines. If the equation is given in the form of the double series of sines and cosines, it must be reduced to the single series. A machine for assisting in this reduction will be described in a later paper in this journal.

The handle of the machine is turned till the gear system is in zero phase, and it is then locked. The disk for each element up to the highest to be used is set to zero phase. The pin on each disk is set to the right of the centre to the amplitude in millimetres of the corresponding component, as indicated by the scale on the

FIG. 11.



Proof of the analysis of a curve by synthesis.

frame. Each disk is rotated in its cup-chuck till the divided circle reads the phase for the corresponding component. The pen chain is adjusted till the pen is on the desired axis, and it is clamped just above the highest element being used. The drawing-board is adjusted to the zero phase position. Then 30 turns of the handle will cause the pen to trace one complete wave of the desired curve. A ten-component curve can be synthesized in about five minutes, while the machine may be set for 30 components and the curve be drawn in 12 minutes.

In the study of sound waves, the synthesizer is chiefly used to verify the correctness and sufficiency of the analyses. The

several elements of the machine having been set to reproduce the separate components in exact sizes and phases, as determined with the analyzer, the tracer will draw the resultant curve. If this resultant is exactly like the original curve which was analyzed, the analysis is correct and complete, and the fact is recorded by tracing the synthetic curve over the original in a contrasting color of ink. Fig. 11 shows the synthetic reproduction of the analysis of an organ-pipe curve drawn by machine on an enlarged photograph of the original.

The harmonic synthesizer is useful for graphically interpreting the analysis of any curve, since it can draw each simple component in its proper size and position as well as the resultant of all the components. The details of such an analysis have been explained elsewhere by the writer.[10] The complex curve at the top of Fig. 12 represents the sound wave from a clarinet. The analysis of this curve showed the presence of 20 components, and the synthesizer was set to reproduce them; the composite is drawn in the upper part of the figure, while each component is shown separately below. These curves are reproduced directly from ink drawings made by the machine.

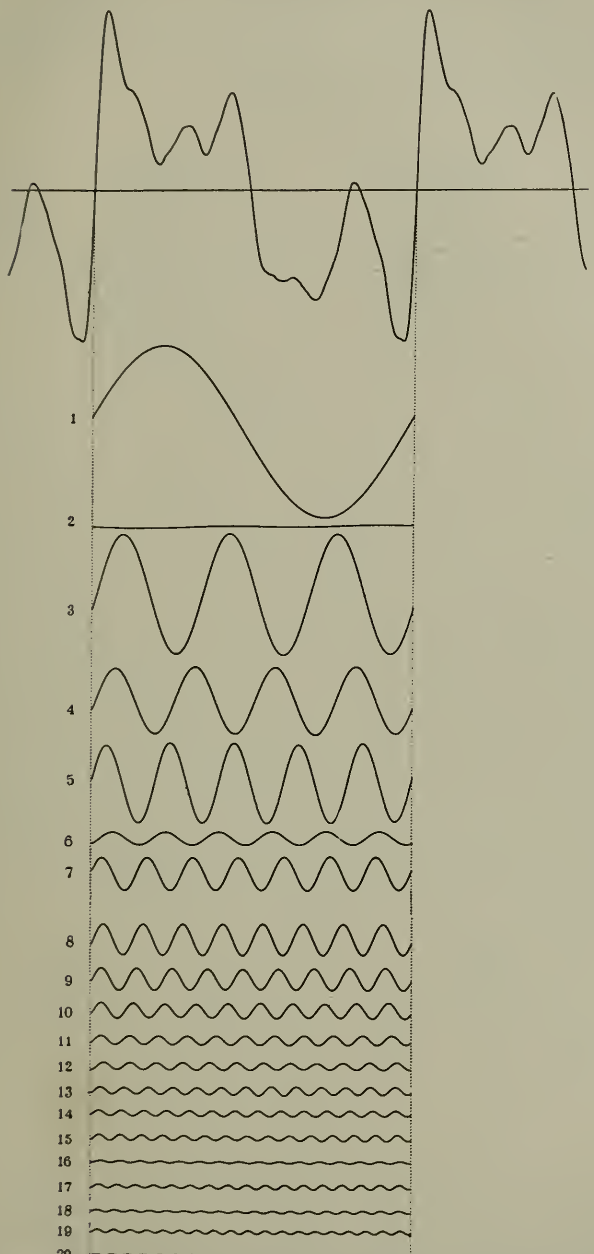
The synthesizer is also used for drawing a curve corresponding to the average of several curves, and for drawing curves of any assumed composition, as in trial analysis. After a photographed curve has been analyzed and the components have been corrected for instrumental disturbances, it is often desired to draw the corrected synthetic curve.

The synthesizer is useful in preparing illustrations for books and papers treating of curves; it would be very difficult to draw the curves of correct form by any other means.

When the synthesizer is set for any curve, if the handle is turned till the phase circle for the first component reads 0°, the circles for the other components show, without calculation, the relative phases, or, as sometimes called, the epochs, of the several components; the tracing point will now be at what may be considered the initial point of the wave, though in general this will not be where the curve crosses the axis.

The mathematician finds the harmonic synthesizer helpful in the investigation of many kinds of curves, and the properties of periodic functions and the convergency of series can be shown graphically.

FIG. 12.

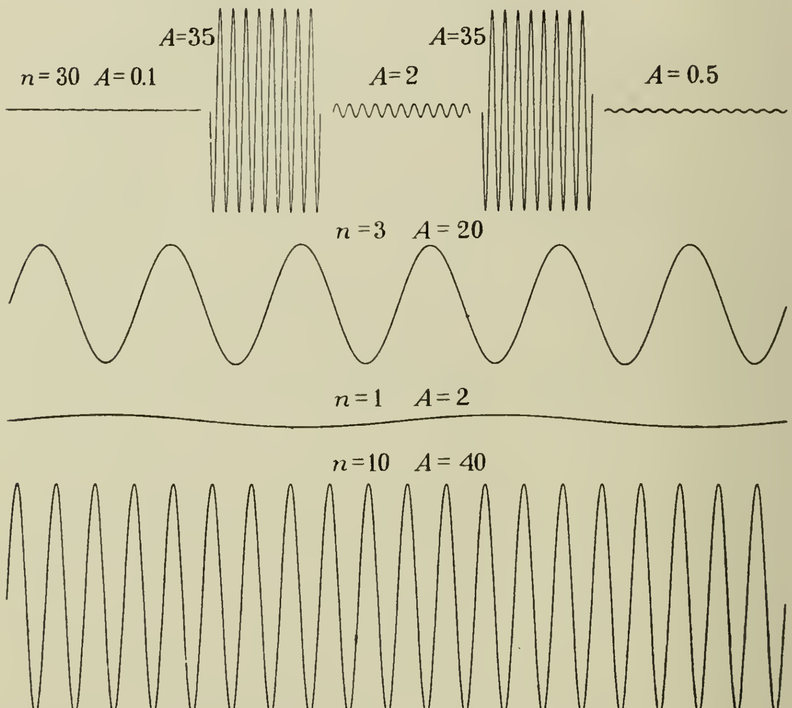


A curve representing the sound wave from a clarinet and its harmonic components.

THE STUDY OF CURVES WITH THE SYNTHESIZER.

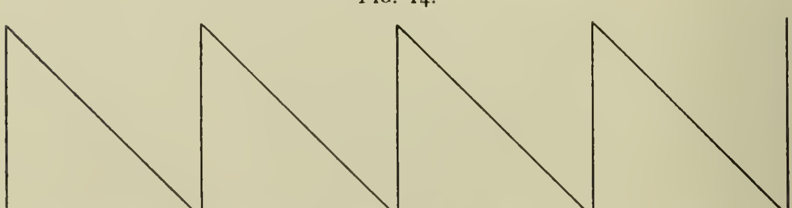
The further usefulness of the synthesizer will be illustrated by several specimen curves which are reproduced directly from the ink drawings made by the machine.

FIG. 13.



Sine curves of various frequencies and amplitudes.

FIG. 14.

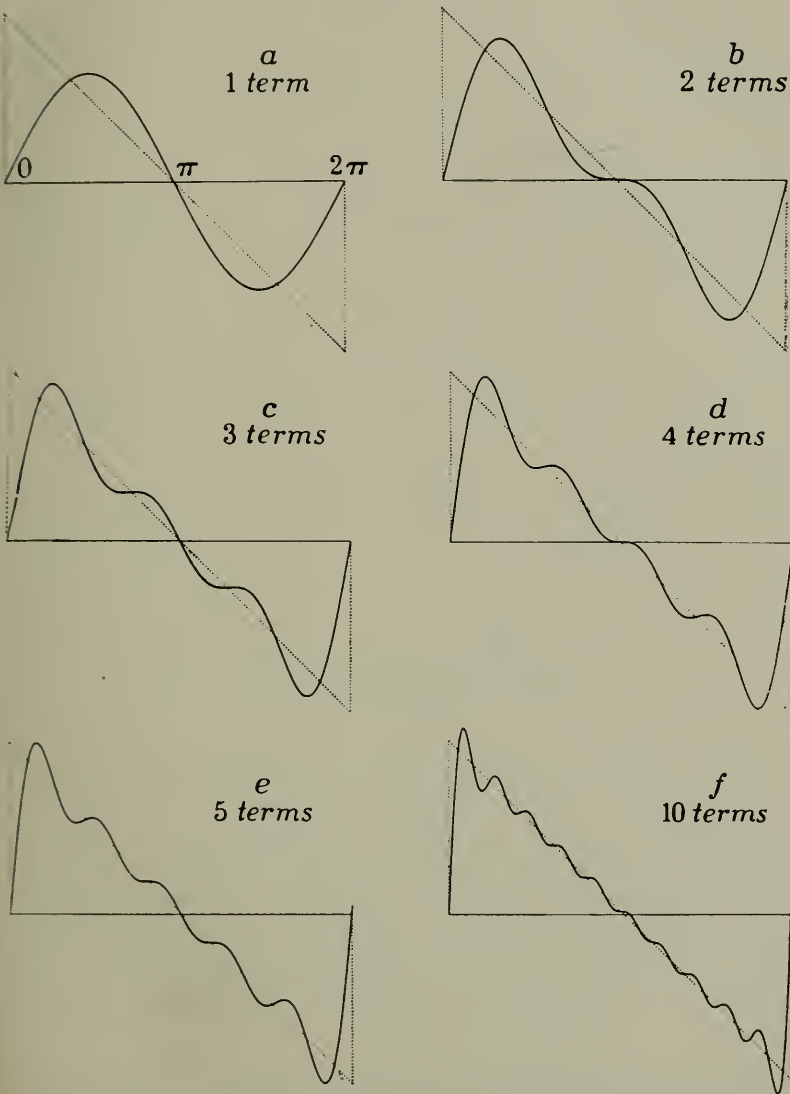


An angular wave-form represented by the equation : $y = 2 (\sin x + \frac{1}{2} \sin 2x + \frac{1}{3} \sin 3x + \ldots)$.

When a single element is used alone, the resulting curve is a *simple harmonic,* or *sine, curve;* it is the simplest kind of a smooth wave-form. Sine curves, while differing in frequency,

n, and amplitude, A, are all equally regular and simple. All the curves shown in Fig. 13 are sine curves.

FIG. 15.



Curves produced by compounding 1, 2, 3, 4, 5, and 10 terms of the series
$y = 2\ (\sin x + \frac{1}{2} \sin 2x + \frac{1}{3} \sin 3x + \ldots)$.

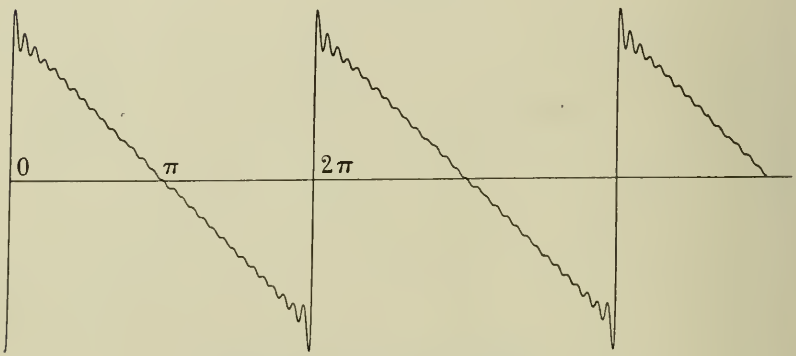
A geometrical figure composed of two straight lines inclined at an angle of 45 degrees, when repeated, produces the angular wave

shown in Fig. 14. The Fourier equation of this curve is an infinite series of the form,

$$y = 2(\sin x + 1/2 \sin 2x + 1/3 \sin 3x + 1/4 \sin 4x + \ldots.),$$

the wave-length being equal to $2\pi = 6.28+$. Each term of the series represents a sine curve. The first 30 terms of this series are set up on the corresponding 30 elements of the synthesizer. The first term only is represented by the sine curve shown at *a*, Fig. 15; the manner in which the addition of successive terms builds up the angular figure is illustrated by *b, c, d, e,* and *f,* which are the curves produced by two, three, four, five and ten terms, respectively, of the series. When 30 terms are included, the

FIG. 16.

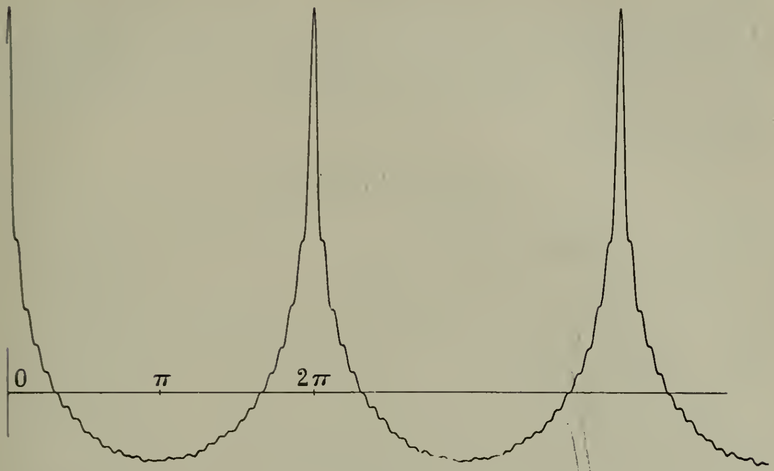


Curve obtained by compounding 30 terms of the series
$y = 2 (\sin x + \frac{1}{2} \sin 2x + \frac{1}{3} \sin 3x + \ldots).$

resultant curve is as shown in Fig. 16. The straight portion which is nearly vertical is the result of the simultaneous action of the 30 elements, all of which at the beginning act in the same direction; but very soon afterwards the highest element reverses, and this is in turn followed by the others, allowing the curve to drop gradually to the axis; at the middle of the wave the resultant must cross the axis, since each individual element, having completed an integral number of half waves, also crosses the axis at this point. These curves are a graphical illustration of the convergence of this particular series.

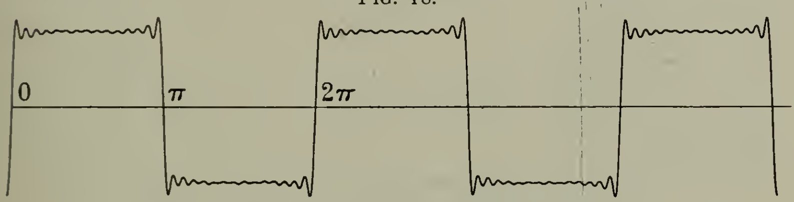
In the curve just described, Fig. 16, the components all start together in zero phase; that is, they all cross the axis in the upward direction at the same point, the middle of the vertical line. When the synthesizer is in this zero position, if each disk is turned 90

FIG. 17.



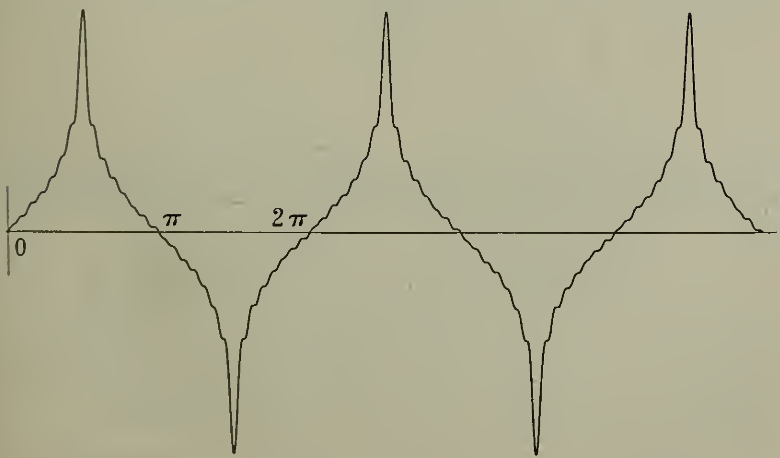
Curve obtained by compounding 30 terms of the series $y = 2$ [sin $(x + 90°)$ + ½ sin $(2x + 90°)$ + ⅓ sin $(3x + 90°)$ + . . .], which is equivalent to $y = 2$ (cos x + ½ cos $2x$ + ⅓ cos $3x$ + . . .).

FIG. 18.



Curve obtained by compounding 15 terms of the series $y = 2$ (sin x + ⅓ sin $3x$ + 1/5 sin $5x$ + . . .).

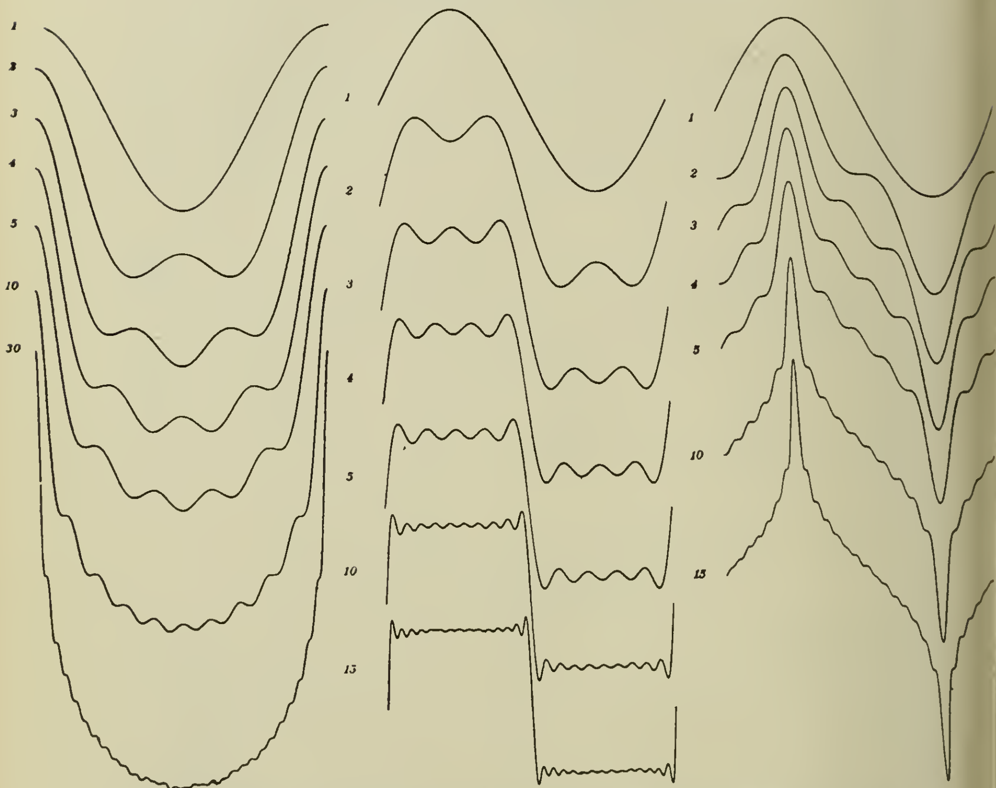
FIG. 19.



Curve obtained by compounding 15 terms of the series $y = 2$ [sin x + ⅓ sin $(3x + 180°)$ + 1/5 sin $5x$ + 1/7 sin $(7x + 180°)$ + . . .], which is equivalent to $y = 2$ (sin x − ⅓ sin $3x$ + 1/5 sin $5x$ − 1/7 sin $7x$ + . . .).

degrees in phase, the components are in effect shifted sidewise, so that the *crests* of all the simple waves coincide. This change in phase will shift the pen from *O*, Fig. 16, to the position shown above *O* in Fig. 17; when the curve is drawn it has the form given in the latter figure.

FIGS. 20, 21, and 22.

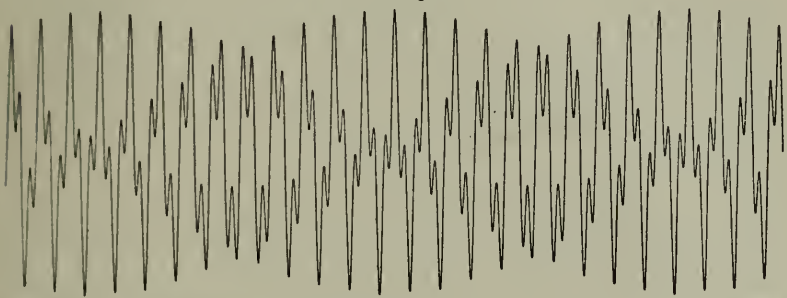


Curves obtained by compounding different numbers of terms of the series corresponding to Figs. 17, 18, and 19, respectively. The number of terms is indicated by the figure at the side of each curve.

If the odd-numbered terms only of the first series are used, the corresponding curve has the form shown in Fig. 18. The synthesizer being set for the curve Fig. 16, it is sufficient to disconnect the clutch *K*, Fig. 7, which causes all the elements on the even-numbered side to stand still, and to draw the curve, Fig. 18, using only the elements on one side of the machine.

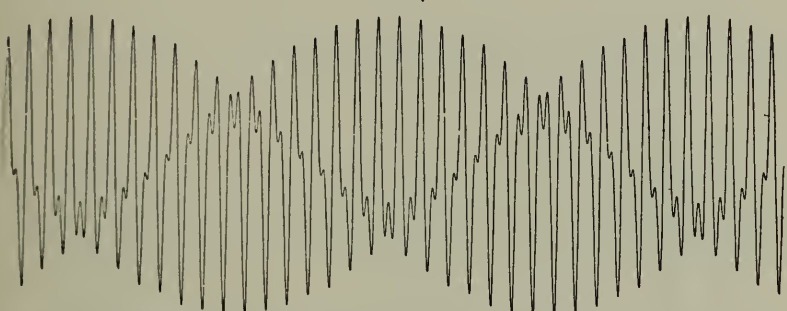
With the same components as for Fig. 18, but with the phases of the alternate terms shifted 180 degrees, a further interesting variation in the curve is obtained, as shown in Fig. 19.

FIG. 23.



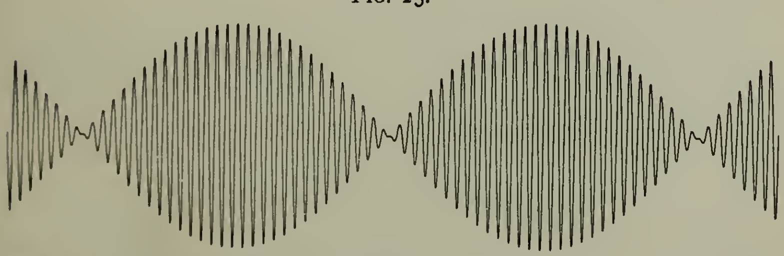
Curve of two components representing the equation $y = 40 \sin 10x + 25 \sin 29x$, the wave-length being 133.3.

FIG. 24.



Curve of two components representing the equation $y = 40 \sin 15x + 25 \sin 29x$, the wave-length being 133.3.

FIG. 25.



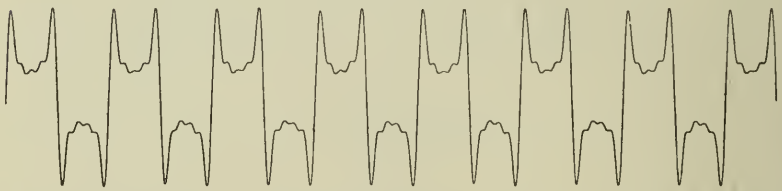
Curve of two components corresponding to beats. $y = 25 \sin 29x + 25 \sin 30x$, the wave-length being 133.3.

If sounds from two different sources were represented by the wave-forms shown in Figs. 16 and 17, respectively, the two

sounds would be of exactly the same loudness and of the *same tone quality,* according to the accepted theory, since they are composed of exactly the same components or partial tones, which differ only in phase. The same remark applies to the two curves shown in Figs. 18 and 19. These illustrations show that the interpretation of the records of complex phenomena requires careful analysis.

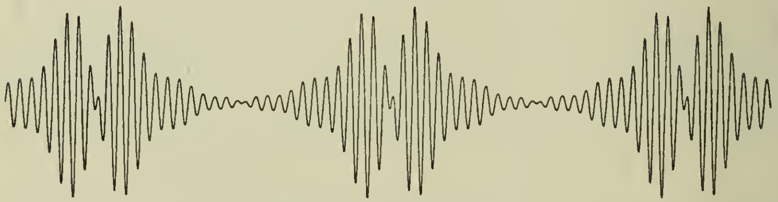
The building up of the curves, Figs. 17, 18, and 19, is illustrated by Figs. 20, 21, and 22; the number of components entering into each curve is indicated by the figure at its side.

FIG. 26.



Curve of 8 components representing the equation $y = 20 \sin 3x + 16 \sin 9x + 12 \sin 15x + 8 \sin 21x + 4 \sin 27x$, the wave-length being 133.3.

FIG. 27.



Curve of 8 components representing the equation $y = 10 \sin 26x + 8 \sin 27x + 6 \sin 28x + 4 \sin 29x + 2 \sin 30x - 10 \sin 24x - 8 \sin 23x - 6 \sin 22x - 4 \sin 21x - 2 \sin 20x$, the wave-length being 133.3.

The curves shown in Figs. 23, 24, and 25 have each two components; the frequencies for the first are in the ratio of 10:29 and amplitudes in the ratio of 8:5. For the second curve, the ratio of the frequencies is 15:29, and of the amplitudes 8:5. The third curve represents the beats produced by two frequencies in the ratio of 29:30, the amplitudes being equal.

The curves of Figs. 26 and 27 are arbitrary combinations of several components which are described in the equations of the legends; these are interesting only as showing beauty of form. The number of curious curves which can be drawn is indefinite; various other forms have been descerihed by Donkin and by Michelson.[8, 9]

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Animals and Plants Which Live in Brines and Raw Salt. (*Overland Guidebook,* Bulletin No. 612, U. S. Geological Survey.)—Just west of Promontory Point station, Utah, is a pond cut off from the Great Salt Lake by the railroad embankment. At times of high water in the lake this reservoir fills by percolation through the embankment, but during the summer this water is concentrated to a brine by evaporation. The deep-pink color of the brine is a phenomenon that appears in salt ponds generally when a certain concentration is reached. In the salt ponds of San Francisco Bay this color is due to a certain bacillus which lives in saturated brines and also in the heaps of salt as it is piled for drainage and shipment. Prohibitive to life as such an environment might be considered, strong natural brines are, in fact, inhabited by a number of minute organisms—animals as well as plants. The pink color disappears in winter or when fresh water is introduced into the pond. The Southern Pacific Company has done some experimental work on preserving piles and railroad ties by soaking them in the pond.

The Production of Acetone from Pyroligneous Acid. M. DARRIN. (*The Journal of Industrial and Engineering Chemistry,* vol. 7, No. 11, November, 1913.)—The purpose of the work reported in this paper is to show the yield of acetone that can be obtained from pyroligneous acid by means of a continuously-operated electric furnace, containing a catalyzer, which converts the acid directly into acetone without necessitating the intermediate production of the acetate.

The raw material consisted of pyroligneous acid obtained by the destructive distillation of Douglas fir mill waste at the half-cord wood distillation plant designed by the author and erected coöperatively by the University of Washington and the United States Forest Service. Before treatment the pyroligneous acid was distilled in order to separate and recover the turpentine, oils, tar, alcohol, etc., since it was thought these substances might have an injurious effect on the catalyzer, and since these by-products are necessarily separated and recovered in commercial practice up to the point where the redistilled acid is neutralized with milk of lime for the manufacture of the gray acetate. At this stage the present practice is to mix the pyroligneous acid with the lime in large tanks until neutralization is complete, as shown by the color change. The principal acid constituent of pyroligneous acid is acetic acid. It is then evaporated to a pasty consistency, dried, and shipped away as "gray acetate of lime" to the acetone plant, where it is destructively distilled in steel retorts, breaking down into acetone and calcium carbonate. The acetone is condensed, washed, and refined in a column distillation apparatus. Among other advantages over the ordinary methods of making acetone from the acetate are higher yields in acetone, lower cost of apparatus and operation, and easy and automatic control assuring uniform results.

RECENT PROGRESS IN THE METALLURGY OF COPPER.*

BY

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I. INTRODUCTION.

The aim of all smelting of sulphide copper ore is to collect the copper in matte which contains usually 40 to 45 per cent. Cu, 35 to 30 per cent. Fe, and 25 per cent. S, and the missing constituents in a slag, a mixture of silicates of iron, lime, etc., low enough in Cu to form a waste product. The iron and sulphur of the matte are separated from the copper by the converter process. This furnishes a crude copper and slag which is too rich in copper to be discarded, and goes back into the ore-smelting; the crude copper is subjected to a fire-refining operation which gives it the mechanical properties demanded by the metal industries.

In the treatment of my subject I intend to cover the progress which has been made mainly during the last ten years in

1. The smelting of sulphide copper ore in the blast furnace.
2. The smelting of sulphide copper ore in the reverberatory furnace.
3. The conversion of copper matte into crude metallic copper.
4. The fire-refining of crude copper to the market product.

II. SMELTING SULPHIDE COPPER ORE IN THE BLAST FURNACE.

For a great many years all smelteries used the roasting and reduction process. In our days the process is found, on this continent at least, only in a few instances, and the two leading representatives are the Canadian Copper Company and the Mond Nickel Company, near Sudbury, Ontario. As the name of the process indicates, we have to deal with two separate operations.

The first is roasting. This aims to eliminate, by oxidation, all the sulphur in excess of that which is required to furnish the 25 per cent. necessary for the matte to be formed in smelting,

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and to oxidize part of the iron, that it may enter the slag. A blast furnace requires, for good work, coarse ore. The lump ore from the mine which is to be roasted is therefore only broken to pass a 3-inch ring, and the coarse product then roasted in heaps. A heap is a truncated pyramid of ore not larger than 3 inches in diameter, built onto a bed of wood and covered more or less with fine ore to check the draft. The wood is ignited, kindles the overlying ore, and this burns with a smouldering fire, for weeks or months, the oxidation of the sulphur and iron furnishing the necessary heat. The Canadian Copper Company has heaps 55 by 100 feet and 10 to 12 feet high, holding 1000 tons of ore with 20 per cent. S, 40 per cent. Fe, 5 per cent. CuNi, and 24 per cent. gangue. A roast lasts from 10 to 12 weeks; the roasted ore retains 10 to 12 per cent. S.

The second step is smelting. It aims at reduction and fusion. The ore is charged with coke and some flux into a blast furnace; it is subjected to increasing temperatures as it descends in the furnace, and to the two reducing agents C and CO. The result is that all oxidized copper is reduced and sulphurized, and with it a varying amount of iron; the two sulphides then form the matte. The remaining oxidized iron of the ore is reduced to the ferrous state and combines with the silica of the ore to a ferrous silicate. Other oxides, such as calcium oxide, alumina, etc., also form silicates, and the combined silicates give the waste slags. This formation of copper matte is made possible by the strong affinity copper and iron have for sulphur. So long as there is sulphur in the charge the copper will combine with it to form Cu_2S and the sulphur still present will be available to form FeS. The difference in specific gravity of matte and slag, 5.5 and 3.5, allows a good separation so long as the temperature in the earth is high enough to keep matte and slag thoroughly fluid, and a removal from different levels of the hearth.

This roasting and reduction process is expensive and slow, and has had to yield to what is called the pyritic process. This is a blast-furnace process in which the oxidation of raw pyritic ore furnishes all the heat necessary to carry on the operation. An ore to be suited for the process must consist mainly of pyrite or pyrrhotite and uncombined silica. As such ores are scarce, pure pyritic smelting is not common, and partial pyritic smelting has taken its place. In this process the lack of heat caused by the

unfavorable composition of the ore is made up by the combustion of coke added to the charge.

Pyritic furnaces have been run for days at a time without any carbonaceous fuel whatever; usually, however, 2 to 3 per cent. coke is added to the charge, the carbon of which is oxidized by the sulphur dioxide in the ascending gases near the throat of the furnace and thus warms the charge. In partial pyritic smelting 6 or more per cent. coke is added to the charge, and this coke is burnt by the blast entering at the tuyères. The chemical distinction between pure and partial pyritic smelting lies in the oxidation of the coke; if all of it is oxidized by the sulphur dioxide of the ascending gases near the throat, we have pyritic smelting; if all or most of it is oxidized by the blast, we have partial pyritic smelting.

The chemical analyses of the blast-furnace gases bring out clearly the difference. Gases from pyritic smelting contain SO_2 6 to 8, CO_2 5 to 16, CO none, free O none or less than 0.8 per cent. vol.; gases from partial pyritic smelting contain SO_2 2, CO_2 up to 14, CO none to 2, free O 8 to 10 per cent. vol.

The tuyère region of the furnace with pyritic smelting is cool; that with partial work is hot.

The sides of the pyritic furnace become covered above the tuyère region with a bosh consisting of siliceous material of the charge, and this is not the case with partial work.

The slag of pyritic work is usually a singulo-silicate; that of the partial process is much more siliceous.

The best exponent of the pure pyritic process is found in the work done by Sticht at Mount Lyell, Tasmania. The blast furnace, 54 by 210 inches at tuyères and 23 feet 7 inches high, with 24 oblong tuyères, 15 by 3.5 inches, puts through in 24 hours 400 to 500 tons charge containing 2.5 per cent. Cu, 25 to 30 per cent. S, and 3 per cent. coke, with 18,000 cubic feet blast per minute, at a pressure of 64 ounces per square inch. It produces matte with Cu 45 to 52 per cent., and slag with SiO_2 35 to 38, FeO 40 to 48, Ca(Mg)O 3.0 to 3.5, BaO 2.0 to 3.0, Al_2O_3 0.5 to 8.3, and Cu 0.3 to 0.4 per cent. Thus 95 to 97 per cent. of the sulphur is burnt off and a matte with Cu 45 to 52 per cent. produced from ore with Cu 2.5 per cent., which corresponds to a concentration of 50 into 1.

Partial pyritic smelting is the process used almost universally

in this country and has been brought to a high degree of perfection.

At Great Falls, Mont., the modern copper blast furnace has been evolved by Klepetko. It has been changed in some details, here and there, to meet local requirements, but the original typical form has been retained and has made its way around the world. The furnace, 56 by 180 inches at tuyères and 14 feet 10 inches high, with 26 tuyères 3 inches in diameter, puts through in 24 hours 350 tons charge containing 6.89 per cent. Cu, 14.7 per cent. S, and 10 per cent. coke, with 10,500 cubic feet air per minute, at a pressure of 40 ounces per square inch. It produces matte with 50 per cent. Cu and slag with SiO_2 37.7, FeO 26.2, CaO 24.4, Al_2O_3 8.0, and Cu 0.32 per cent. Thus 78 per cent. of the sulphur is burnt off, and a concentration affected of 7 into 1.

The striking economic features of the two records are the smelting power (Mount Lyell, 6.8 tons per square foot hearth area in 24 hours, against 5 of Great Falls), and the concentration of ore into matte (Mount Lyell, 50 : 1, against Great Falls, 7 : 1). They bring out the favorable character of the ore of Mount Lyell in comparison with the refractory nature of the material treated at Great Falls.

At Anaconda, Mathewson, in 1905, joined two neighboring furnaces, 180 inches or 15 feet long, by removing the facing end-walls and filling in the 21-foot space with a new furnace; he thus obtained a hearth 15 + 15 + 21 = 51 feet long. This worked so satisfactorily that when another remodelling became necessary in 1906 he erected a furnace 87 feet in length, retaining the standard Great Falls width at tuyères of 56 inches. This monster furnace, 56 by 1044 inches at tuyères and 13 feet 4 inches high, with 150 tuyères 4 inches in diameter, puts through in 24 hours 1400 tons charge (or 5.88 tons per square foot hearth area), containing 6.79 per cent. Cu and 13.80 per cent. S and 8.70 per cent. coke, with 52,070 cubic feet air per minute, at a pressure of 40 ounces per square inch. It produces matte with 43 per cent. Cu and slag with SiO_2 39.3, FeO 24.2, CaO 25.2, Al_2O_3 6.2, and Cu 0.3 per cent. There is burnt off 70.58 per cent. of the sulphur, and the concentration is 6.3 into 1. The advantages accruing from such a large furnace lie in the saving of labor and of fuel, and in the improvement of the smelting as a whole.

Very few smelteries have enough ore to treat to permit following the example of Anaconda; large-size furnaces erected at

present are 20 to 30 feet long inside at the tuyère-level; the width ranges from 44 to 56 inches, depending upon the coarseness of the ore. The working height ranges from 13 to 16 feet.

With such large furnaces the preparation of charge, the removal of matte and slag, the supply of air necessary to burn the coke and sulphur, and the recovery and handling of flue dust have shown great improvements over older devices.

In a modern plant the components of the charge are collected in hopper-shaped bins provided with gates and weighing devices and trains of side-discharge cars travelling beneath. These receive the required amounts of ore, flux, and coke, are hauled to the feed-floor on tracks running along the sides of the furnaces, and their contents dumped on one side and then on the other onto deeply inclined cast-iron plates extending from the feed-floor into the furnace. The desired distribution of the furnace materials is attained by allowing the surface of the charge in the furnace to sink more or less before new material is introduced. In this way the ore, flux, and fuel falling from the dumping cars can be delivered near the side or the centre of the furnace.

At the works of the Cananea Consolidated Copper Company, the Tennessee Copper Company, and the Calumet and Arizona Copper Company the Dwight-Messiter ore bedding system has been introduced by means of which ores for the blast or reverberatory furnaces are sampled, bedded, reclaimed, and delivered mechanically to the furnace bins at a cost of 9 cents per ton.

With most furnaces the melted matte and slag flow together from the furnace beneath a tymp, which traps the blast, into a fore-hearth, usually 14 feet in diameter and 5 feet high, in which the matte separates from the slag. The matte is tapped periodically into ladles which go to the converting department, while the slag overflows continuously either into slag cars to be hauled to the dump, or is granulated by a stream of pressure-water which carries away the granules.

The blast is supplied in most cases by Roots or Connersville rotary pressure blowers. In recent years the turbo-blower is gaining favor, as it delivers a definite amount of air irrespective of the pressure prevailing in the furnace. This is not the case with the rotary pressure blowers.

The gases issuing from the open throat of a blast furnace are cool, 150° to 250° C. in a reducing fusion and in true pyritic smelt-

ing; they are hot in partial pyritic work, 300° C. and over. With a speed of about 750 feet per minute they carry along with them dust and volatile components of the charge. Most of the dust is readily collected if the gases are sufficiently cooled and their speed retarded to 150 feet per minute. The remaining dust and most of the volatile materials used to pass off into the open. Three methods of collecting them have proved economically successful: the Roesing wire system at Great Falls, Mont.; bag-filtration at the Mammoth smelter, Shasta, Cal.; the Cottrell system of electric condensation is being tried out at Anaconda, Mont., on a large scale.

In the Roesing system, steel wires are suspended in the chamber through which pass the gases. The friction caused between the travelling gases and the stationary wires causes a retardation of the velocity, and with it a settling of the suspended particles. At Great Falls, Mont., Nos. 6 and 8 gauge wires form a horizontal screen, with openings ⅝ inch square, from which are suspended No. 10 gauge wires 16 and 20 feet long. The chamber holds 1,200,000 wires. It is 348 feet long, 176 feet wide, and 21 feet high. From the entrance to the chamber, for a distance of 150 feet, and back from the exit, also for 150 feet, the space is wired; the intervening space is left free from wires. The purpose of this arrangement is to collect dust in the entrance division and fume in the exit division. The arrangement has proved a complete success. The wire system is shaken mechanically from the outside for 30 minutes at intervals of 60 to 90 days to dislodge the adhering dust and fume; this collects in the hoppers of the floor and is gathered.

At the Mammoth smelter, Shasta, Cal., the gases from the blast furnaces are cooled to 100° C. by drawing with a fan through a series of air-cooled soft-steel pipes, admitting at the same time some air, and then forcing them through a bag-house which contains 3000 suspended woollen bags 34 feet long and 18 inches in diameter. These filter the gases and hold back all solid matter. Furnace gases from pyritic smelting contain SO_2 and SO_3. The corroding effect of SO_3 is neutralized by the Sprague process, in which zinc oxide produced from blende on a Wetherill grate is fed into the gas current; this oxide unites with uncombined SO_3 and forms harmless $ZnSO_4$.

The Cottrell process aims to collect dust and fume by having

a high-potential direct current jump through the cooled gases travelling in the flue, from the needle-points of one pole to the plate-poles of the other. This causes particles of dust and vapor to travel toward the plates with a speed which is proportional to the charges and to the potential gradient between point and plate. This process has proved very effective at Garfield, Utah, for cleaning converter gases. The large-scale experimental work carried on at Anaconda, Mont., is very promising.

The handling of flue dust has shown many improvements.

Briquetting, the old standard method, is falling into disuse. The Tennessee Copper Company pours matte from a ladle over a bed of flue dust. The matte takes up the dust, and the dust furnishes part of the siliceous addition necessary for converting. The Cananea Consolidated Copper Company pours flue dust and liquid converter slag together into a slag-bowl, and this, when filled, is emptied over an inclined slag-dump, where the contents passing downward form lumps suitable for blast-furnace work. The Copper Queen Smeltery, Douglas, Ariz., feeds flue dust and liquid converter slag into a revolving conical cast-iron drum, and discharges the two, intimately mixed, in the form of balls. The Mason Valley Mines Company, near Wabuska, Nev., has in operation two 100-ton Dwight-Lloyd sintering machines in which flue dust with fine sulphides and some coke-fines are blast-roasted to hard cellular cakes.

III. SMELTING SULPHIDE ORE IN THE REVERBERATORY FURNACE.

Until about twenty years ago most sulphide copper ores were smelted in the blast furnace; about ten years ago reverberatory-furnace smelting became quite important; the great improvements made within the past two or three years have made the reverberatory furnace so prominent that, *e.g.,* Anaconda has given up its blast furnaces.

We have seen that the blast furnace requires lump ore if it is to do good work. This lump ore must run high in copper if the operation is to be profitable; but high-grade ores are not abundant, hence the prevailing medium and low-grade ores have to be enriched by ore-dressing work. The enriched product, the concentrate, is a fine-sized material, which is exactly what the reverberatory furnace requires for good work. The losses of copper mineral in ore dressing have been large. The recent advances made

by flotation methods to treat the slimes produced in ore-dressing have been so successful that the loss in copper mineral has been greatly reduced. There is therefore less hesitation than formerly to enrich ores suited for blast-furnace work by ore-dressing work, and to smelt the entire product of the mine in the reverberatory furnace.

We shall see how the improvements made, in the construction of the reverberatory furnace and the method of handling, in the substitution of oil for grate-burnt bituminous coal, and, lastly, in the use of fuel dust, have caused reverberatory smelting to be cheaper per ton of charge treated in our smelting centres than blast-furnace smelting.

A. Roasting Furnaces.

The concentrates furnished by the ore-dressing plant contain from 8 to 30 per cent. Cu; they are not rich enough to be smelted direct for a matte with from 40 to 45 per cent. Cu, and have to be rough-roasted to eliminate some sulphur and to oxidize some iron.

Mechanical roasting furnaces are especially suited for the rough-roasting which is to reduce the sulphur content from over 30 to about 10 per cent. Montana smelteries have constructed and operated many mechanical roasting furnaces which embodied various principles for moving the ore over the hearths of reverberatory and kiln roasters. Of the great variety of furnaces, the multiple-hearth MacDougall type has outlived all the others. A MacDougall furnace is a vertical cylinder with superimposed horizontal hearths, central rotating shaft with radial stirring arms provided with rabble-teeth set at a proper angle. The ore, fed mechanically at the top, is turned over by the teeth and moved on one hearth from the periphery toward the centre; it drops through a slot onto the next following hearth, is moved there in an opposite direction and drops through slots near the periphery onto the third hearth; it continues to travel in this manner until it is discharged from the bottom hearth into a receiver. The air necessary for oxidation enters through side doors and travels in a direction opposite to that of the ore.

Of the MacDougall type of furnace, three forms are found at copper smelteries: the Evans-Klepetko, the Wedge, and the New Herreshoff.

The Evans-Klepetko furnace is 16 feet in diameter, 18 feet

high, has 6 hearths, a water-cooled shaft 9 inches in diameter, and two removable rabble-arms to a hearth. The roasting capacity at Great Falls was 40 tons in 24 hours, the arms making 1 revolution in 53 seconds; it is 75 tons in 24 hours since the speed of the arms has been increased to 1 revolution in 38 seconds. With high-sulphur ores the arms are water-cooled, with low-sulphur ores air-cooled; if there is not enough sulphur present, say under 28 per cent., for the ore roast without extraneous heat, a fireplace is added to deliver a flame to the second or third hearth from the top.

The Wedge furnace is 20 feet in diameter, 22 feet high, and has 7 hearths. The characteristics are: a 4-foot air-cooled central shaft, for the support of the air- or water-cooled arms, running on roller-bearings, and a furnace top serving as a mechanical dryer. The capacity is 100 tons ore in 24 hours with 35 per cent. S reduced to 7 per cent.; the number of revolutions of the shaft varies with the character of the ore.

The New Herreshoff furnace is 20 feet in diameter, 23 feet high, has 6 roasting and one drying hearths; the central shaft is 18 inches in diameter, carries hollow rabble-arms having vertical partitions extending to near the end. Air forced in at the bottom of the shaft rises, travels outward in one division of a rabble-arm, returns in the other, is delivered to the air-shaft, 3 feet 4 inches in diameter and enclosing the rabble-arm shaft, warmed, and discharged onto the bottom hearth. The capacity is the same as that of the Wedge furnace.

B. Matting Reverberatory Furnaces.

We have seen that in smelting in the blast furnace C and CO generated from the combustion of the coke are the reducing agents; in the reverberatory furnace S is the leading reducing agent; the carbonaceous fuel burned serves only to furnish the heat necessary for the chemical reactions to take place between ore and flux.

In discussing furnace practice I shall confine my remarks mainly to the modern long-hearth furnace with waste-heat boilers, fed semi-continuously, and fired with coal, oil, and fuel dust.

The immediate forerunner of the modern furnace was a furnace with hearth 50 by 20 feet and grate 10 feet by 5 feet 4 inches, treating three 35-ton charges (*i.e.*, 105 tons) in 24 hours, or

236-pound charge per square foot hearth area, with a fuel ratio of 3 : 1. The charge of hot calcines was dropped from the hoppers in the roof and spread; the side doors were closed and luted, and the fire was urged. When the fusion was completed, the furnace was slightly cooled to stiffen the slag; this was skimmed and part of the matte tapped. Then a new charge was dropped onto the remaining matte and the smelting operation repeated. The new charge cooled the furnace considerably, so that a large part of the eight hours of smelting was taken up to bring the furnace again to a full smelting heat, and then only the remaining part given to smelting proper.

In 1904 Mathewson developed at Anaconda the principle of feeding small charges at short intervals near the fire-bridge of a coal-fired furnace 112 feet long by 19 feet wide (*e.g.*, 15 tons charge every 80 minutes and 3000 pounds coal every 40 minutes); he skimmed slag every 4 hours, allowed a bath of matte to accumulate to the extent of 200 tons, and grated every 4 hours. Some of the matte was tapped when needed for converting. This method of operating kept the temperature uniformly high. The result was a greater tonnage, a higher fuel ratio, and a longer life of the furnace. The furnace with hearth 112 by 19 feet treated in 24 hours 300 tons charge or 302 pounds charge per square foot hearth area with a fuel ratio of 4.8 : 1.

The great advantage of the method of working is striking, and was adopted everywhere.

All reverberatory matting furnaces at present are provided with waste-heat boilers, introduced at Anaconda by Klepetko. The former practice was to burn as little fuel as possible, because the hot gases from a furnace went to waste; with the advent of the waste-heat boiler the practice was reversed, as much fuel as the furnace could stand was burned, and thereby the smelting power greatly increased.

Bituminous coal, run-of-mine or screened, has been the common fuel for the reverberatory furnace. Mathewson has shown that with the best coal available in Montana there was little advantage in increasing the length of a furnace beyond 110 feet, and that 100 feet is a practical limit.

Oil was used as a fuel at Humboldt, Ariz., in 1906; it was adopted at Cananea, Mexico, in 1908; and later at Steptoe, Nev.; Hayden, Ariz.; Garfield, Utah, and at other smelteries. The

advantages of atomized oil over bituminous coal burned on a grate are important. The calorific power is higher, the feeding is continuous, and the loss of heat from the fire-box—estimated by J. W. Richards at over 25 per cent.—is avoided, as the oil is blown onto the hearth. The result is that the temperature obtained is higher, the smelting power greater (400 against 300 tons in 24 hours), the heat efficiency larger and the amount of the flux needed smaller, as slags with a higher percentage of SiO_2, 45 against 40 per cent., can be made on account of the high temperature. The temperature of the furnace at the oil burners is so high that the distance between roof and hearth of furnace has to be large, not less than 6 feet, if the life of the silica roof is not to be abnormally short. On account of the continuous firing and the high temperature, the furnace can be longer than with grate-burned bituminous coal; thus Sörensen put into successful operation at Steptoe, Nev., a furnace with hearth 140 feet long and 19 feet wide in which there were smelted, *e.g.*, from April to July, 1914, per day, 685 tons charge, or 0.2915 ton per square foot hearth area with a consumption of 0.562 barrel oil per ton.

The feeding of oil through high-pressure atomizer burners is simple and clean in comparison with the supplying of coal to a grate and the time-consuming and exhausting work of cleaning grates.

The latest step in the improvement of fuel supply is the use of *fuel dust*. This was tried by Sörensen near Salt Lake City in 1906, and by Shelby at Cananea in 1907–08, but was not successful. D. H. Browne, of the Canadian Nickel Company, took up the matter again in 1909 and concluded that the troubles of Sörensen and Shelby were due mainly to stoppage of flues by ashes and to imperfect feeding of dust; the former was overcome by drying the coal to a water-content of 1 per cent. or less, and by grinding it to a fineness of 95 per cent. passing a 100-mesh screen, the latter by improved apparatus, common with cement kilns in the eastern part of the country. In December, 1911, a reverberatory furnace fired with fuel dust was put into successful operation. The furnace, 112 feet long and 19 feet 9 inches wide, has 5 burners, 3 feet 4 inches apart, treats 450 tons charge in 24 hours with a fuel ratio of 6.77 : 1. In working out the problem, the mode of feeding the ore was changed from the Anaconda manner to dropping the larger part of the charge through 6-inch

pipes in the roof placed 2 feet apart, and the smaller part through four 11-inch openings near the fire-end. The ore delivered at the sides covered the side walls so that ore was smelted on top of the slag-matte bath and along the sides. The ore is fed at one side all the length of the wall, at the other to the tap-hole placed near the throat. The original hearth of magnesite brick now protected by matte and ore has been replaced by the usual siliceous material.

At Anaconda the Browne method of working has been so successful that fuel-dust firing has replaced grate-firing; the smelting has been so cheapened that blast-furnace work, as stated before, has been stopped. The Anaconda furnace, 124 feet long by 21 feet wide, has 5 burners placed 3 feet 3 inches apart, and 6-inch feed pipes on the sides placed 19¼ inches apart for 74 feet from the fire-end; beyond this the furnace requires fettling. The new method of charging has reduced the matte-bath from the original 175 tons to 50 tons. The furnace treats in 24 hours 500 tons charge with a fuel ratio of 7.5 : 1; with grate-firing the smelting power was 260 tons with a fuel ratio of 4 : 1.

The latest Anaconda furnace is 147 feet 2 inches long and 25 feet wide; it has 10-inch feed-holes, 24 inches centre to centre; it is expected to treat in 24 hours 800 tons charge with a fuel ratio of 7.7 : 1.

IV. CONVERTING COPPER MATTE.

The conversion of copper matte, first attempted by Raht in 1866, at Ducktown, Tenn., and made a practical process by Manhès in 1880, forms one of the landmarks in the metallurgy of copper. In the process air in the state of fine division is forced through liquid copper-iron matte held at a temperature of about 1150° C. in a vessel lined with siliceous material; the Fe is oxidized to FeO and simultaneously combines with SiO_2 to Fe_2SiO_4, while SO_2 passes off as a gas. The slag is poured off and the remaining Cu_2S blown, with the result that Cu_2O and SO_2 are found, and the Cu_2O as soon as formed acts upon unoxidized Cu_2S, forming Cu and SO_2. This process was brought to a high degree of perfection in this country, and held its own until 1909, when Pierce and Smith, at Baltimore, succeeded in replacing the easily corroded siliceous lining of the converter by the resistant magnesite brick and adding the silica required for slagging oxidized iron by charging siliceous ore. Basic converting has shown so many advantages over the original acid process that it has

almost entirely replaced the latter. I shall confine my remarks to basic converting.

A characteristic of all matte converters is that they are side-blown, and not bottom-blown, as is the steel converter. There are in operation two classes of vessels, the horizontal and the vertical; typical forms are those of Garfield, Utah, and of Great Falls, Mont.

The Pierce-Smith converter at Garfield is a horizontal cylindrical shell, 26 feet long and 10 feet in diameter, supported by three sets of carrying rollers. The shell is lined with magnesite, holds 30 tons copper, has on the blowing side 32 tuyères with 1.5-inch openings 18 inches above the bottom; at the pouring side there is an opening with spout for introducing the charge and pouring the copper, and at the top is the throat for the passage of the gases into the dust chamber. The cylinder is rotated in a horizontal plane by means of wire ropes.

The Great Falls converter of medium size is an upright cylindrical steel shell, 12 feet in diameter, and, with hood, 13 feet 8 inches high, holding 12 to 14 tons copper. It has 15 2-inch tuyères 12½ inches above the bottom, and a throat for the receiving of charge, the pouring of slag and metal, and the passage of gases. It is carried by two short trunnion-shafts, attached to friction wheels running on friction rollers, and is rotated in a vertical plane by spur wheel and pinion. This 12-foot converter has made such an excellent record that it is being introduced at most smelteries. Great Falls and Anaconda now have 20-foot converters, but most smelteries prefer smaller sizes.

The mode of operating in both vessels is similar. The vessel, suitably prepared and heated, received a certain amount of liquid matte which is followed by a suitable quantity of siliceous ore; it is blown with air at 11 to 14 pounds pressure until the iron is oxidized and slagged; the slag formed is then poured. Fresh liquid matte and ore are charged and blown; these operations are repeated once or twice until the vessel is filled with white metal, *i.e.*, practically pure cuprous sulphide with 80 per cent. Cu; the white metal is now blown in the usual way to blister copper to be poured.

The slag formed contains SiO_2 26 to 28, FeO 50 to 55, Al_2O_3 3 to 4, CaO under 1 per cent.; the blister copper about 99 per cent. Cu.

The Pierce-Smith 26- by 10-foot vessel holds about 40 tons matte; it takes 20 hours to furnish 45 tons blister copper from 45-per cent. copper matte, or, roughly, 30 minutes per ton of copper. The Great Falls 12-foot vessel holds 12 to 19 tons matte; it takes 4 hours and 20 minutes to furnish 13 tons of copper, or 20 minutes per ton copper. Thus the work of the upright is quicker than that of the horizontal; the life of the lining is also longer.

The two leading considerations in the operation of the basic converter are the blowing temperature and the SiO_2-content of the slag. If the blowing temperature exceeds 1150° C., the lining is quickly corroded; hence greatest care is taken to keep the temperature down by regulating the blast, by charging cold copper-bearing materials, or by allowing slag to accumulate in the vessel, as this retards conversion. The SiO_2-content of the slag is of importance, as a low SiO_2 favors the oxidation of Fe to Fe_3O_4, which adheres to the magnesite lining and protects it, while high SiO_2 favors the oxidation of Fe to FeO, which enters the slag and favors corrosion of the lining.

V. FIRE REFINING OF COPPER.

The aim of the process is to remove from metallic copper foreign substances which impair its physical properties. As practically all the copper received by our refineries is converter metal with about 99 per cent. Cu, and cathode metal, which is still purer, the chemical aspect of the process is comparatively simple.

The researches of Wanjukow and Stahl have thrown new light upon this question. They conclude that (1) Zn, Fe, Co, and Sn are completely removed at the beginning of the oxidizing stage, and S at the reducing or poling stage; (2) that the elimination of Ni, Pb, As, and Sb continues through the entire process and imperfect; and (3) that Ag and Bi are removed only to a very small extent.

The operation is carried on in a reverberatory furnace. It involves (1) charging, (2) melting, (3) partial oxidation of the fused metal in order that the Cu_2O formed, which is soluble in copper and has a smaller affinity for O than the foreign substances removable by fire, may oxidize the impurities and cause them to rise to the surface to be skimmed, and (4) reduction of the Cu_2O by poling to give the metal the required degree of malleability and ductility.

The improvements made in the process are mainly mechanical. Formerly the metallic copper was charged by hand and the refined copper ladled. This limited the size of a furnace; through one door 8 tons of metal can be charged per hour; the use of pneumatic lifts increases this amount to 17 to 20 tons. The mechanical chargers of Prosser and Ladd, and Clarke-Antisell handle 150 tons cathodes in 2 hours with 2 men.

Ladling the copper from a 25-ton furnace into ingots weighing on the average 17 pounds takes about 4 hours; ladling with a trolley-supported ladle permits casting twice the amount in the same time. This is about the limit. Furnaces used to hold 15 tons copper, later their capacity was increased to 40 and 50 tons, but this was the limit until A. R. Walker constructed his casting machine, which handles as much as 400 tons copper in less time than is necessary to cast 40 tons with a trolley-supported ladle. With mechanical charging and mechanical casting the size of the charge to-day is governed solely by the ability to construct a furnace, especially a furnace bottom, which will stand such enormous weights, and by the skill of the refiner in holding such a bath of copper at the desired pitch; *i.e.,* that the copper shall not be over- or under-oxidized.' Modern furnaces hold from 80 to 400 (usually 200 to 250) tons copper, starting with cathodes, and finishing with ingot, wire bar, and cake copper.

[A number of lantern slides of copper plants, roasting and reverberatory furnaces, converters and other machinery were shown and described during the course of the lecture.]

Locked-up Potash. (*Overland Guidebook,* Bulletin No. 612, U. S. Geological Survey.)—About two miles northeast of Superior, Wyo., are the Leucite Hills, which are made up largely of igneous rocks in the form of volcanic necks, sheets intruded into the stratified rocks, and dikes cutting across the sedimentary strata. Associated with these intrusive rocks are volcanic cones and lava flows. These rocks have long been objects of scientific interest because of their unusual character. Lately they have attracted additional interest by reason of the potash-rich mineral, leucite, they contain, which may some day be utilized if a process can be found for extracting the potash cheaply. It has been estimated that the igneous rock of the Leucite Hills contains more than 197,000,000 tons of potash.

Unusual Features in a Lift Span Bridge. ANON. (*Engineering Record,* vol. 72, No. 22, November 27, 1915.)—Provision for a shifting river channel by using a lift span and five other truss spans of identical design to make possible the future transfer of the towers to lift any span desired, the use of counterweight chains of special design instead of the usual wire cables, and the adoption of a folding cast-iron counterweight to control the balance of the lift span and chains are some of the unique features of the recently-completed bridge over the Arkansas River near Pine Bluff, Ark. The bridge, which is a combined railway and highway structure, is approximately 3010 feet long, with 1610 feet of steel structure and 1400 feet of timber trestle. The steel section consists of seven riveted spans, six of which are 239 feet 4 inches centre to centre of end pins and one 149 feet 7 inches long.

The channel of the Arkansas River is liable to shift at any time. At the Cotton Belt bridge, a few miles below Pine Bluff, the channel shifted from one side of the river to the other, necessitating the construction of a new swing span, so that the bridge now has two swing spans. It was therefore considered desirable in this case to use a type of construction such that the movable span could be shifted to any part of the bridge in case of a change of location of the channel. The spans were accordingly made all alike and provided with all arrangements for attaching the lifting and control mechanisms to any one of the equal spans. The weight of the chains is balanced by disks of cast iron so arranged that they are picked up by the counterweight as it rises, thus adding to its weight to compensate for the otherwise unbalanced length of chain.

Elasticity and Strength of Stoneware and Porcelain. J. E. BOYD. (*Proceedings of the American Society of Mechanical Engineers,* New York, December 7 to 10, 1915.)—The widely-extended growth of elaborate construction work incident to the rapidly-increasing development of electric transmission projects has prompted a closer study into the mechanical properties of the clay products serving as insulating members in electric transmission structures. With the object of making possible the design of insulators of greater mechanical strength and determining a more definite factor of safety, a series of stress-strain tests have been conducted on clay products in tension and compression.

The results indicate that the modulus of elasticity of stoneware and porcelain is practically the same in tension as in compression. The modulus of elasticity of porcelain is about 10,000,000, while that of stoneware ranges from 6,000,000 to 9,000,000, depending on the material. The compressive strength of porcelain and high-grade stoneware in a column 16 inches long and 1 inch in diameter is about 20,000 pounds per square inch. The stress-strain diagram is practically straight up to 7000 pounds per square inch. The tensile strength of stoneware ranges from above 1100 to 2200 pounds per square inch.

THE LIGHT-REFLECTING VALUES OF WHITE AND COLORED PAINTS.*

BY

HENRY A. GARDNER,

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THE attention of engineers is being constantly called to the relative value of different types of artificial illuminants for interior spaces. Very little thought, however, has been given to the light-reflecting power of the interior surfaces where such illuminants are used. That the surface constitutes quite as important a factor as the type of illuminant is indicated by the tests herein described, where the illumination of an interior space lighted with a tungsten lamp varied from 12 per cent. to 67 per cent. when different surface colors were used.

Although considerable work has been done on the light-reflecting power of wall papers,[1] the constantly-decreasing tendency to use paper, on acount of its insanitary properties, and the steadily increasing use of wall paints of the oil type, especially in hospitals [2] and public buildings, have necessitated a reconsideration of the problem, since different methods of determination would be required in many cases for two such different substances as paper and paint.

A search of the literature on illumination has produced one article which gives a series of carefully-made photometric measurements on the reflective value of paints. This is by Louis Bell,[3]

* Communicated by the Author.

[1] "Surface Brightness and a New Instrument for Its Measurement," Dow and Mackinney, *Illum. Eng.*, vol. 3, Nov., 1910, p. 655. "Apparatus for Measuring Light and Illumination," Dow and Mackinney, *Elec. World*, vol. 60, Aug. 17, 1912, p. 364.

[2] "The Sanitary Value of Wall Paints," H. A. Gardner, Bull. Scien. Sec. Paint Mfrs.' Assn. of U. S.

[3] "Examination of the Coefficient of Different Tints in Its Relation to Indirect and Semi-indirect Lighting," Louis Bell, *Elec. World*, vol. 65, Jan., 1915, p. 211.

who calls attention to the fact that traces of carbon in a paint (gray) or dust of a painted surface immensely decrease the illuminating value. He advocates the use of light-colored oil paints on account of their washability. Some of his readings are shown below. The composition of the paints is not given, and the colors are only described by terms.

Color	Kind of paint	Per cent. reflection
White	Oil	65.7
Extremely faint cream	Oil	64.0
Light cream	Oil	52.8
Light cream	Water	52.0
Very faint greenish	Oil	46.0
Very faint greenish	Water	45.8
Faint gray	Oil	45.6
Pale-gray buff	Water	44.0

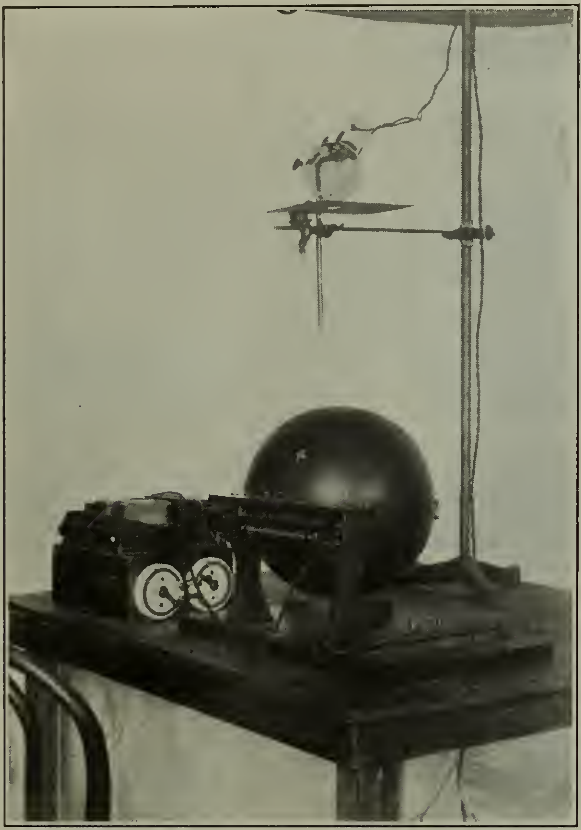
Unfortunately, direct readings on a photometer could probably not be made with great accuracy on very dark paints or on those which present a very high enamel-like lustre. The apparent necessity of devising more appropriate means of measuring the light-reflecting powers of paint, by a method which could be used for all shades and tints, as well as all degrees of matte and gloss surfaces, led the writer to experiment with a number of types of apparatus. Painted samples for experimentation were first prepared by sizing paper and applying two coats of a number of white and colored paints of which the composition was known. The apparatus that proved most suitable for determinations of the "coefficient of reflection" [4] is shown in Figs. 1 and 2, as arranged by W. F. Little,[5] who made the readings. A disk 3¼ inches in diameter, coated with the paint in question, was placed at the centre of an integrating sphere and was illuminated by the light of a concentrated filament lamp shining through an opening in the top of the sphere. The light fell on the disk at an angle of 45 degrees. The interior of the sphere received only such light as had first

[4] Defined in the 1915 Report of the Committee on Nomenclature and Standards of the Illuminating Engineering Society as "the ratio of the total luminous flux reflected by a surface to the total luminous flux incident upon it."

[5] Engineer in Charge of Photometry, Electrical Testing Laboratories, New York.

been reflected by the paint. To effect a standardization a flat block of magnesium carbonate (commercial) was substituted for the disk. The value of the coefficient of reflection of this block was taken as 88 per cent., in accordance with the experiments of

FIG. 1.



Apparatus for determining coefficient of reflection of painted surfaces.

Nutting, Jones and Elliott.[6] The readings were made with a portable photometer. The results are shown in the following tables and on the insert sheet which presents samples of the colored paints on paper.

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[6] "Results of Some Possible Reflecting Power Standards" in the *Transac. of the Illum. Engrg. Soc.*, vol. 9, No. 7, 1914.

TABLE I.

Effect of the Vehicle on the Coefficient of Reflection of White Paints.

	Coefficient of reflection
Lithopone in dark-colored raw linseed oil	61
Lithopone in very light-colored flat varnish	67
White pigment mixture in light-colored semi-gloss varnish	66
White pigment mixture in light-colored gloss varnish	66
Special white pigment in flat varnish	61.2
Special white pigment in high-gloss varnish	61.2

TABLE II.

Effect of Slight Tints on the Coefficient of Reflection of White Pigments Ground in Flat Varnish.

	Coefficient of reflection
Pigment A, free from impurities (very white)	66
Pigment AA, containing traces of iron giving yellow color	64
Pigment AA, tinted with ultramarine blue to correct yellow shade, producing slight greenish tint	64
Pigment A, with 1½ per cent. lampblack tinting color (light gray)	44
Pigment A, with 1 per cent. lampblack tinting color (gray)	27

TABLE III.

Colored Paints.[7]

MADE ON A MIXED WHITE PIGMENT BASE, TINTED WITH CHROME YELLOW, CHROME GREEN, PRUSSIAN BLUE, PARA RED, OCHRE SIENNA, CARBON BLACK, ETC.

	Coefficient of reflection
Light cream	66
Light pink	60
Light yellow	58
Light blue	55
Light greenish yellow	54
Light buff	52
Light green	42
Light terra-cotta	41
Medium terra-cotta	39
Light greenish blue	36
Medium blue	32
Warm green	19
Medium green	14
Red	12
Blue, dark	12
Green	11

[7] The exact color is shown on the insert sheet.

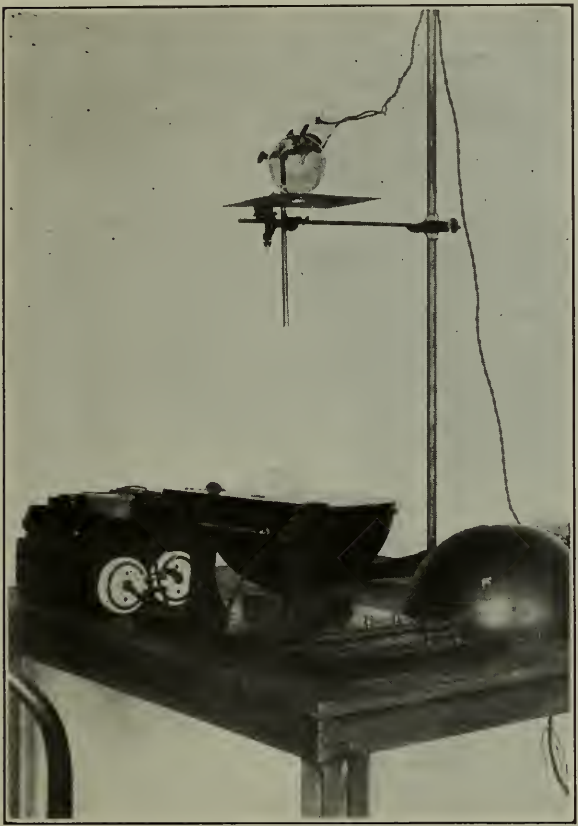
CHART SHOWING COEFFICIENT OF REFLECTION OF VARIOUS WALL COLORS COMPARED WITH A BLOCK OF WHITE MAGNESIUM CARBONATE (88%)

Insert to "The Light Reflecting Values of White and Colored Paints," by Henry A. Gardner.

TABLE IV.

	Coefficient of reflection
Luminous calcium sulfid paint	54.4
Aluminum paint	48.

FIG. 2.



View showing painted surface in place within integrating sphere.

The most interesting of the results are those on flat, semi-gloss and high-gloss paints, all of which apparently have substantially the same illuminating value when prepared of the same pigment mixture with oils or varnishes of the same degree of color. This is an important development, since it allows the use of the type of paint best suited for the lighting equipment of a room: direct, semi-indirect, indirect, etc. Although flat paints may retain

their whiteness for a greater period of time, semi-gloss and gloss paints are preferred in many instances on account of their greater resistance to frequent washing.

Factory Illumination.—The illumination of factories, railroad terminals, and department stores has been given great consideration of recent years, increased output, improved workmanship, and a minimum of accidents having resulted in nearly every instance where better lighting systems have been installed. In such places, wall treatment as a means for conserving the illumination afforded by modern illuminants has generally been adopted. These advances have come as a result of practical observations which show that the rays from powerful lights, falling upon dark brick or stone walls, give less light to a room than the rays from less-powerful lights falling upon similar walls that have been painted in light colors with dust-resisting, washable paints. From the standpoint of economy it is of interest to record the fact that the monthly cost of illuminants for lighting dark-walled factories may be enormously reduced by painting the interiors in light colors.

The customary process of treating factory walls is to first apply a coat of flat (matte surface) white paint and later to apply a coat of gloss white. This is the recommended treatment when the modern indirect or semi-indirect forms of lighting fixtures are used, since the gloss finish repels the lodgement of dust and may be most easily washed For the ceilings, however, a flat or semi-gloss paint is better than a high gloss, since the former types distribute the light to better advantage. In factories where direct-lighting fixtures are used with modern illuminants, or where even less-modern forms of illumination are in evidence (swinging oil lamps, etc.), the flat or semi-gloss oil paints are also advisable, on account of their glare-preventing and light-diffusing properties.

The question has been raised as to whether colored paints should be advised for use where direct lighting fixtures are employed, since white is not always the most desirable color under some forms of very strong light. For instance, the traveller who for the first time approaches a tropical city is surprised to see the buildings and dwellings painted blue, pink, green—in fact, every conceivable color. In Havana there exist ordinances prohibiting the use of white paints on the exterior of buildings, on account of the glaring effect produced by the tropical sun. The selection of

the colors is left to the discretion of the property owner. Similarly, it is possible that in some factories paints having a slight greenish or other tint would be desirable, since a small amount of some colors may reduce the glare but will not materially reduce the illumination. The wall tint to be used should, however, be studied under the particular form of light present in a room, since artificial illumination of some types exerts a marked action upon certain colored surfaces,[8] giving them shades or tints which are entirely different from those observed in daylight or by other illuminants. The tint which is most pleasing under the light used, and of sufficient reflective value, should be adopted.

Schoolrooms, Public Buildings, and Dwellings.—A. C. Rapp,[9] of Pittsburgh, was the first to call attention to the necessity of a careful selection of colors for schoolrooms, in order to bring out the greatest mental and physical effort among the occupants. The adoption of his suggestions would doubtless result in greater efficiency in the schoolroom and a higher degree of physical fitness among the students. In his paper Rapp quotes some experiments conducted by Dr. L. E. Landon on students placed in rooms treated with various colors. The effects of the colors may be summed up as follows:

Black.—Melancholia. Decreased work.

Red.—Temporary stimulation followed by a reaction, accompanied by nervousness and headache.

Blue.—Calmness and seriousness.

Green.—Increased vitality. Happiness.

Yellow.—Increased vitality. Amiability.

That the same consideration should be given to the selection of wall colors for all public buildings, stores and dwellings as well as schools, is apparent. It is the writer's contention, however, that the lighter tints of the most desirable colors should be used, in order to increase the illumination to the greatest possible extent. The darker colors could be used for borders and dadoes to produce pleasing contrasts to the main body of the work. These

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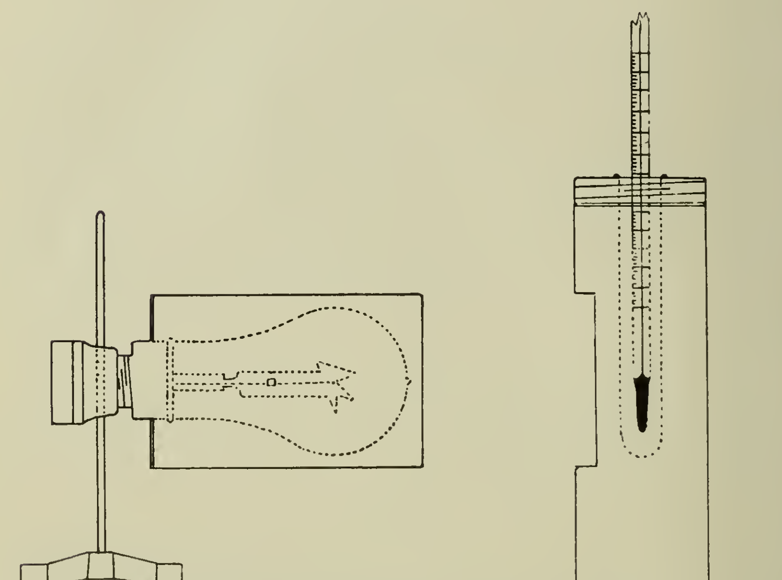
[8] A Standard for Color Values," D. McF. Moore, *Proc. Illum. Eng. Soc.*, vol. 5, 1910, p. 209. "Reflection Coefficients," P. F. Bauder, *ibid.*, vol. 6, 1911, p 85. "Influence of Colored Surroundings on the Color of the Useful Light," *Elect. World*, 1913, vol. 61, p. 410.

[9] "Surfaces and Colors for Hospitals and Schools," A C. Rapp, Bulletin 38, Scientific Section Paint Mfrs.' Assn. of U. S.

suggestions are in line with those advanced by Parsons and Smith,[10] who studied the physiological effect of colors in study-rooms at the United States Naval Academy. They advocated ceilings painted white, slightly tinted with yellow, and light greenish-yellow walls which by tungsten light would assume a pleasing green color.

Carriers.—Subterranean travel has increased to such great proportions in our large metropolitan centres that the problem of

FIG. 3.



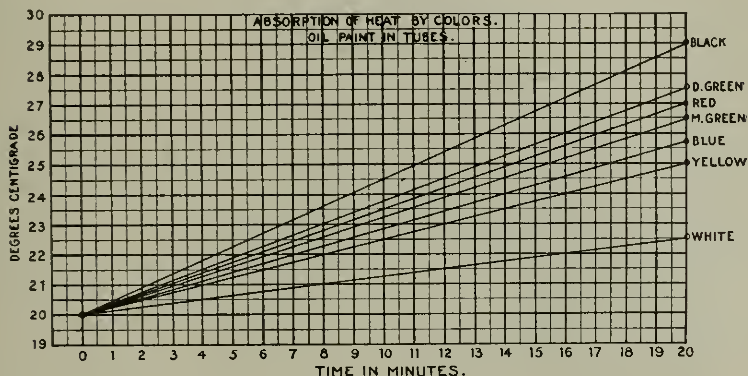
Apparatus for determining heat absorption of various colors.

lighting subway cars is one of growing importance. Every paintable surface in the cars should be coated, preferably with gloss paints in white or the lightest tints. Even the floors should be painted, not with dark-gray or similar light-absorbing colors, but with neutral buff or light tints of sufficient strength to prevent them from being readily soiled. By the use of hard drying, abrasion-resisting paints for this purpose, the floors may be maintained in a sanitary condition by daily washing. The darkest

[10] "The Illumination of Study-rooms," *Elec. Review and West. Elec.*, vol. 57, Aug., 1910, p. 428.

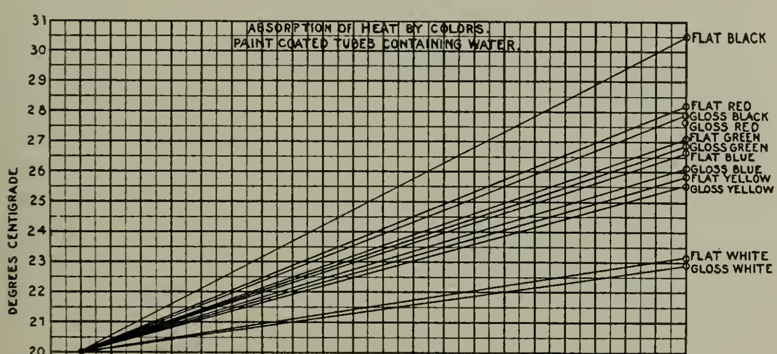
sections of tunnels may be rendered brighter by the occasional application of water-resisting white paints, where the expense of such procedure is justified. Not only in subway cars, but in

DIAGRAM I.



surface cars and railroad passenger coaches, similar paints should be used. The present method of finishing car interiors in artificial mahogany grain could be superseded by the application of

DIAGRAM II.



white and light-tinted paints. Reading at night without eyestrain would then be more of a possibility for the traveller.

Temperature of Colored Surfaces.—Dark-colored paints not

only absorb light rays, but heat rays as well. The presence of only a small amount of black in a white paint (gray) makes an astounding difference in the heat absorption. The writer and L. P. Hart have conducted some tests on those colors which are used by the grinder in producing colored paints on a white base. In one series of tests the colors were ground in linseed oil to a stiff paste which was placed in glass tubes upon which were focussed the rays of a powerful nitrogen-filled Mazda lamp (see Fig. 3). In another series of tests the outside of the tubes was painted with the same colors ground in linseed oil to produce a glossy surface or ground in turpentine to produce a flat surface, 10 c.c. of water being subsequently placed in each tube, all of which were submitted to the same light test. The rise in temperature of the paint and the water is recorded in Diagrams I and II. The colors used were as follows:

Paranitraniline red (20 per cent. on calcium carbonate base).
Chrome yellow, 100 per cent.
Prussian blue, 100 per cent.
Dark green (100 per cent. mixture of blue and yellow).
Medium green (20 per cent. dark green on barium sulphate base).
Black (100 per cent. carbon black).
White (white lead and white zinc, 50 per cent. each).

Zirconium-iron Alloys for Lamp Filaments. U. S. Patent No. 1,151,160, August 4, 1915. (*Metallurgical and Chemical Engineering,* vol. xiii, No. 15, December 1, 1915.)—Attempts hitherto made to produce commercially useful alloys of zirconium have not been very successful, as brittleness of the metal has characterized such alloys. Moreover, it has been found extremely difficult to produce alloys of the metal by direct combination with other metals. According to a patent granted to John L. Brown, of Baltimore, Md., however, it has been found possible to make satisfactory alloys of zirconium and iron and other metals by reducing mixtures of compounds containing these metals. The alloys thus produced are of a type hitherto unknown among metallic zirconium combinations. They exhibit little tendency to oxidize and are resistant to most chemical reagents. They are also tough, malleable, and ductile. The value of these alloys for lamp filaments is that they have the property of selective radiation and possess a remarkably high degree of luminescence at relatively low filament temperatures. The presence of titanium, tantalum, and columbium gives alloys that offer certain advantages for special purposes.

THE PRODUCTION OF LIGHT BY ANIMALS.*

ULRIC DAHLGREN,

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LUMINOUS PLANTS.

Most of the unicellular light-bearing forms that we have been considering have some more or less weighty reasons for being called plants. The bacteria were so called on account of their physiological resemblance to the Eumycete fungi, as well as their less fundamental morphological resemblances to the Schizophytes, to which they are more commonly referred by morphological botanists.

Their physiological similarities to the fungi are happy from the viewpoint of the student of luminosity, because we find that the only forms of plant life with an autogenous light production are the fungi.

Light has at times been reported to be generated by diatoms and some flowering plants, but such appearances have been proved to be deceptions, which will be dealt with in a chapter devoted to such false appearances. It is in the fungi alone, then, among the real plants, that we ever encounter any actual organic source of light.

These organisms consist, in their most common individual state, of vast numbers of threads or strands of cells, called Hyphæ, that are massed and woven together in such a way as to form the structures so well known to us as "toadstools," mushrooms, or sometimes simply as fungi. These more apparent parts of the plant that we see in field and meadow rising from the ground, or in the woods projecting from the side of a tree or standing on an old stump or mass of rotting wood, are only the "flowers" or spore-bearing buds of the actual "plant," which consists of a mass of interlaced and branching strands of the woven hyphæ that live all the year round under the surface, away from the light, and deriving nourishment from dead or living organic matter instead of from inorganic matter by photosynthesis, as the majority of plants do (see Figs. 1 and 2).

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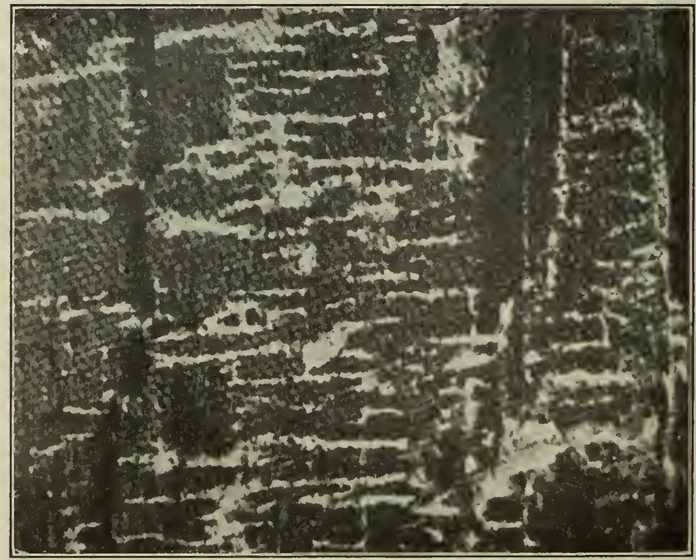
* Continued from page 127, December, 1915, issue.

This root-like plant that lives and branches out under ground or ramifies between the bark and trunk or through the wood of some infested tree is known as the mycelium. The familiar fruit- or spore-bearing bodies, with their artistic forms and colors, are the toadstools or " fungi," and are known technically as the sporophores or " fruit-bodies " (see Fig. 2).

Of the many hundred species of these fungi, a considerable number of them produce a more or less visible light in all or part

FIG. 1.



Photograph of the mycelium of a parasitic fungus as shown in the wood of a tree trunk by splitting the trunk longitudinally. (After Atkinson, in his book on "Mushrooms.")

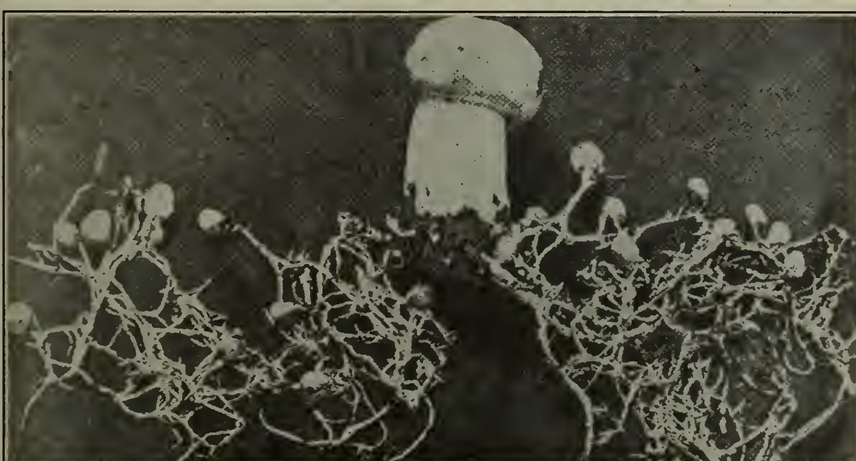
of their bodies and for all or only a certain part of their lives. This fact has been mentioned casually by many writers from the greatest antiquity to the present day, while modern writers have taken the subject up in more or less detail in modern times and studied rather superficially its ecology and physics, but very little of its structural side.

Already the great observers of ancient times had mentioned the luminosity of decaying wood. Aristotle and Plinius have recorded it, although their knowledge of systematic biology was not enough to correctly interpret the phenomenon. Robert Boyle,

Spallanzani, and Alexander von Humboldt studied this question of luminous wood in the seventeenth, eighteenth, and nineteenth centuries and determined several points, such as the necessity of oxygen, and the fact that it was not a heat-producing combustion of the wood. Also, Carradori, Gärtner, Böckmann, and Placidus Heinrich wrote about this luminous wood and remarked upon its odor being like that of most fungi; also, that most all woods, when cut and placed in a moist place, would begin to light under the bark.

Derschau, in 1823, began to show that the light in question was

FIG. 2.



Photograph of an entire mushroom plant to show relation of sporophore or fruit-body to the root-like mycelium from which it grows. (After Atkinson, in his book on "Mushrooms.")

probably of an organic origin when he showed it to emanate from root-like strands in the wood rather than from the real wood substance itself. This structure he called *Rhizomorpha,* and as such it was further studied by Buchof, Noeggerath, Nees von Esenbeck, Schmitz, Theodore Hartig, and deBary, who all came to the conclusion that it was the wood and not the *Rhizomorpha* that shone.

Before most of their papers appeared, however, Heller had published the fact that it was the fungus (mycelium) that lighted and not the wood. He named the fungus *Rhizomorpha noctiluca,* and was followed by others, who gave different names to the particular fungi they found in luminous wood: R. Hartig named it

Rhizomorpha fragilis Roth; Hoffmann called it *Rhizomorpha subterranea,* and R. Hartig, at a later date, identified it correctly as the mycelium of the well-known German fungus commonly called "Hallimasch," and known to science as *Agaricus melleus.*

But this particular mycelium is not the only one that shows light in rotting wood or other organic matter. A large number of others have been found to do the same with varying degrees of brightness. As we will see later, this light is, like the bacterial light, a continuous one so long as the age and condition of the plant permit of its production. These broken and torn mycelia glow and shine as spots and strands of luminous material in the broken substance of decayed stumps, trunks, and limbs of fallen trees in forests all over the world, and have been familiar sights to forestmen, hunters, and others since recorded observations in the literature of many countries and peoples. Their ghostly light has been the subject of fairy stories, superstition, romance, and narratives.

It was soon found that the fruit-body or sporophore of this mycelium does not shine at any time, and the same was proved for some other forms. Collingwood, however, as Hoffmann describes, found a toadstool in Borneo that showed a strong light from both mycelium and fruit-body. The youngest fruit-bodies or buttons shone as brightly as the mycelium, while the light grew dimmer as the toadstool became older. Undoubtedly other fungi are to be found in which the fruit-body alone lights, while the mycelium shows no light at any time.

The luminous forms of fungi are not closely associated, but are members of several widely-separated groups of the Basidomycetæ. The following kinds have been noted as luminous species, either altogether or in some part of their body: *Agaricus melleus,* Europe; *Agaricus olearius,* South Europe; *Agaricus Gardneri,* Brazil; *Agaricus igneus,* Amboina; *Agaricus noctilucens,* Manila; *Agaricus phosphorens,* Australia; *Agaricus prometheus,* Hong Kong; *Pleurotus lampas,* Australia; *Pleurotus illuminans,* Australia; *Pleurotus incandescens,* Victoria, N. S. W.; *Pleurotus nidiformis,* Australia; *Panus incandescens,* Australia; *Collybia cirrhatus,* Bohemia; *Mycena illuminans,* Java; *Omphalia martensii,* Borneo; *Locellina illuminans,* Celebes; *Marasmins sp.,* New Guinea; *Clitocybe illudans,* North America; *Panus stypticus,* North America; *Polyporus noctilucens,* Angola; *Polyporus luci-

dens, Polyporus annosus, Corticum sp., Dictyophora phalloidea, Brazil; *Xylaria hypoxylon, Xylaria cookei, Tramates pini, Polyporus sulphureus,* and *Illeodiction cerebrum.*

The light from most luminous fungi is not, perhaps, as bright from a given surface as it is in the case of some other organisms. It varies in the different photogenic forms, and, as has been said, is a continuous light whose intensity is varied in only two ways: by controlling the amount of oxygen, and by the time of life and development of the plant.

A good idea of its appearance in one of our American forms, *Clitocybe illudans,* is furnished by a letter sent to the professor of botany at Princeton University in 1900 by an intelligent observer, Mr. Wilfred W. Shaw, who lives in Port Deposit, in the State of Maryland, U. S. A. Part of this letter reads as follows:

"I should be glad to know if the phenomenon is merely extraordinary to me because of my ignorance of botanical matters, or whether it is really of unusual occurrence.

"In a field beside my parsonage—(I am minister of the Presbyterian church at this place)—is growing a clump of fungi. Three days ago my younger boy gathered two, as they were of such a brilliant orange hue, about five inches across; and his mother put them in a small vase on the dining-room mantel-piece.

"That evening I was out and returned home about 11 o'clock; going into the dining-room, where everything was dark, I noticed something luminous on the mantel-piece, and, on making my way across the room, found it to be these fungi. Underneath where the gills are there was a strong luminosity, like a phosphorescent glow. I looked carefully round to see if there was any ray of light coming from any quarter which the fungus might have caught; but there was none. I put my hands close to it; but the light remained the same.

"On Saturday evening I went into the dining-room again to test this light and found the glow to be seemingly just as strong."

Thus we get a good idea of the comparatively strong light emitted by this fungus (*Clitocybe illudans*) (see Fig. 3). Atkinson and other mycologists further describe it as being dark in the very earliest fruit-body stage, brightest at its prime of nearly full size, and the light dying out as its spores are shed and age begins to shrivel it.

A most important point concerning the same species has been

mentioned by Hard in his mushroom book. This plant, in its luminous condition, also generates sufficient heat to make it possible to measure it with an ordinary glass thermometer. Further work should be done on this important point, as the production of heat by practically all other luminous organisms has been shown to be almost a negligible proportion, less than one per cent. in most cases, and only measurable by delicate physical apparatus in the laboratory.

Clitocybe illudans, (Fig. 4) is found in dead stumps and tree

FIG. 3.

Scene in the woods at night, showing *Clitocybe illudans* growing on an old stump (left) and *Panus stypticus* growing on the other side (right). (Drawn by E. Grace White from descriptions.)

trunks on cut forest that has been down for about three years. It is very abundant and is not edible. In color it is a bright yellow or orange on top, with a somewhat lighter stem and gills. As Mr. Shaw has shown, the brightest light is from the gills and casts a glow on the surface from which this toadstool protrudes. Fig. 3 gives a good idea of its appearance in the forest.

The question of the particular part of the fruit-body from which light emanates in fungi has been further looked into by Tulasne, who found that the glow was not superficial, but emanated from the entire internal substance of the luminous fruit-body, al-

though it was brightest as it showed from the gills on the under side. This is probably due to the fact that the form and large surface of the gills or hymenaria of the toadstool allowed more light to radiate, as well as supplied a larger amount of oxygen to the neighboring tissues.

The cells of the hyphæ have been sectioned and studied by the writer and are represented in Fig. 5. While it was not possible

FIG. 4.

Photograph of *Clitocybe illudans* from life. (After Atkinson, in his book on "Mushroooms.")

to see the exact source of light in the cells, it is presumed that the luciferine was secreted into the vacuoles shown in the figure, and that the material was consumed as fast as secreted *in situ* in the vacuoles.

In one single species of fungus, however, Volkens has described another method of oxidization. This is a species, *Mycena illuminans,* from Java, and when the luminous fruit-body was examined it was found that the seat of brightest light was in a thick slime with which the upper surface of the cap was covered. Upon

touching it the slime stuck to the hand, and, when withdrawn, the fingers glowed with the luminous substance. This species appears to offer a good opportunity for studies on the chemistry, etc., of the light production.

Another brightly-glowing toadstool is described by Gardner, who while travelling in Brazil, near the town of Natividade, in the province of Goyaz, saw a group of boys one evening playing with some luminous objects that he took at first to be light-produc-

FIG. 5.

Section from the outer part of a "Cap" of *Clitocybe illudans*, showing several hyphæ with their internal structure. Nuclei are very small. Cytoplasm is vacuolated, and luciferine is probably secreted and buried in their spaces. (Drawing by E. Grace White.)

ing insects. Upon looking closer he saw that it was a species of *Agaricus,* afterward named *Gardneri* by Berkeley, and at his request the children took him to the locality in which they had found the fungi. Here he found them growing in large numbers on the leaves of a palm. They were called "Flor de Coco" by the natives, and the light streamed from all surfaces of the plant. As has been said of so many luminous plants and animals, he also said of this, that "one could read by it."

Of all countries in the world, Australia is the one that contains the most numerous and brightest fungi in its forests. Lanterers

describes the brilliancy and abundance of *Panus incandescens* growing in groups on the sides of tree trunks and glowing with an emerald-green light.

Also Alpine describes the light of *Pleurotus candescens* in these same wide forests, growing on half-rotted wood in great abundance. He tells how clumps of this toadstool will glow for at least a week after being gathered in the woods in the month of April. For the first few days the mycelium also glowed near its attachment to the stem, but later only the fruit-body or sporophore was visible as a source of luminosity.

The manner and extent of lighting of the mycelium of several fungi have already been touched upon. In daylight the mycelia of fungi are usually of a translucent whiteness; single small strands in a growing condition are practically transparent. Where the strands are larger, and when strands of any size are numerous and matted together in many layers, the color becomes pure white, like snow, and for the same reason that snow is white, namely, on account of the included air-spaces. Some mycelia are colored, however, and are yellow, black, brown, etc.

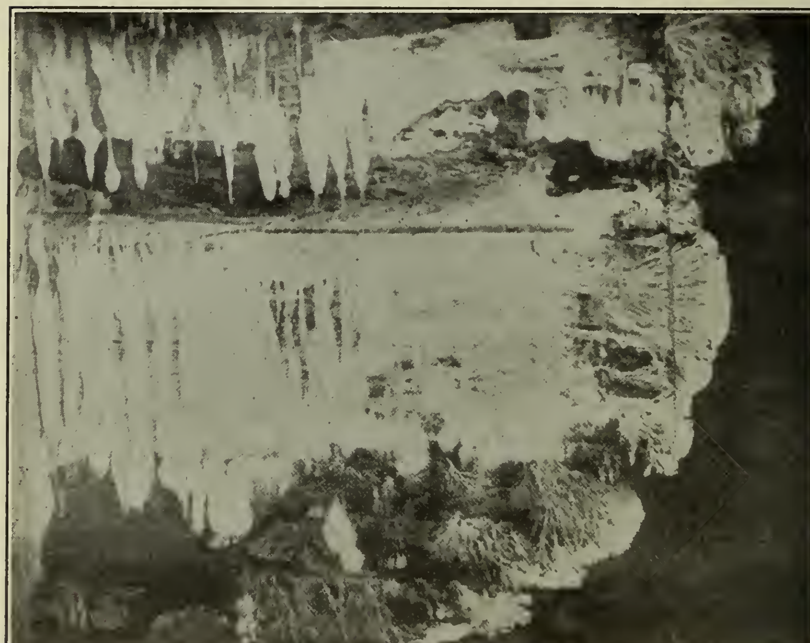
The mycelia are almost always concealed under ground or in earth, manure, or rotten or even living wood (see Figs. 1 and 2). They can almost always be seen by tearing the loose bark off of fallen and half rotten tree trunks or stumps and in the humus of rotted leaves in the forest. They are also found upon the surface of old wood, manure, etc., in caves, mines, etc. Fig. 6 shows a beautiful mycelium growing on the surface of a plank in an abandoned mine near Wilkes-Barre, Pa. Mycelia will also grow when covered by a glass case or bell-jar and kept properly cool and moist on the surface of bread, wood, manure, etc.

Thus we see that the light from mycelia can be seen under a variety of conditions. Most commonly it has been reported and can be seen as luminous spots and threads in moist, rotted-in wood in the forest. Its most vigorous manifestations, however, are visible between the bark and the wood of newly-rotted tree trunks, where it appears in sheets of livid bluish or greenish light when the bark is torn off. A very accurate and natural description of the light under these conditions is given by George Masse, in his "Text-book of Fungi," from an account by Berkeley, as follows:

"A quantity of wood had been purchased in a neighboring parish, and was dragged up a very steep hill to its destination.

Among it was a log of larch or spruce, it is not quite certain which, twenty-four feet long and a foot in diameter. Some young friends happened to pass up the hill at night and were surprised to find the road scattered with luminous patches, which, when more closely examined, proved to be portions of bark or little fragments of wood. Following the track, they came to a blaze of white light which was perfectly surprising. On examination,

FIG. 6.



Photograph of a piece of board from an abandoned coal mine near Wilkes-Barre, Pa. This board is covered with the mycelium of *Agaricus melleus*. (After a photograph by Atkinson in his book on "Mushrooms.")

it appeared that the whole of the inside of the bark of the log was covered with a white byssoid mycelium of a peculiarly strong smell, but unfortunately in such a state that the perfect form could not be ascertained. This was luminous, but the light was by no means so bright as in those parts of the wood where the spawn had penetrated more deeply, and where it was so intense that the roughest treatment scarcely seemed to check it. If any attempt was made to rub off the luminous matter it only shone the more

brightly, and when wrapped up in five folds of paper the light penetrated through all the folds on either side as brightly as if the specimen was exposed. When, again, the specimens were placed in the pocket, the pocket when opened was a mass of light. The luminosity had now been going on for three days."

Where the luminous mycelia of such fungi as *Agaricus melleus* grow on the wooden supports of mines they sometimes show a wonderful brilliancy. At times certain passages in a mine may be entirely covered with such a growth and the resulting light so brilliant that one has no need of any other illumination. Thus Derschau describes the conditions mentioned above as follows: "*Der Steiger bemerkte mir, dass man in dieser Strecke an einzelnen Stellen keiner Lampe bedürfe, indem das Holzwerk hinreichend leuchte. Die Grubenlichter wurden dann gelöscht, und es fand sich wirklich die Strecke stellenweise matt, aber doch so weit erleuchtet, dass man die zu nehmende Richtung erkennen konnte. Bei näherer Betrachtung fand ich das Holzwerk mit bläulich leuchtenden Linien und Punkten überzogen, welche die einzelnen Tierstöcke und Kappen bezeichneten, und an einigen Stellen so hell schimmerten, das ich bei diesem Schein die Fläche meiner Hand wahrnehmen konnte. Meine begleiter wollten dies dem faulenden Holze zuschreiben, so oft ich aber nach jenen leuchtenden Punkten griff, gerieten immer Teile der Pflanze . . . in meine Hand.*"

The luminous mycelium can be used for study in a way that is not possible with the luminous fruit-body. The mycelium lives for years, and it is assumed, in view of our somewhat limited observations and experiments, that the light of a luminous form is continuous so long as active metabolism is going on. We know of no fungoid form that, like the bacteria, is luminous at some times and not at others, even during its healthy growth and reproduction processes.

Molisch, in order to take up the study of the light fungi under favorable laboratory conditions, undertook to make pure cultures in flasks, dishes, etc., on various suitable nutrient media. He was not the first to make cultures of various kinds. Many observers, as Heinrich, learned to place bits of wood in such fashion that they would speedily become inoculated with some luminous mycelium, and elaborate directions were often given for the preparation of such experiments.

Molisch first started by bringing about twenty pieces of barks, stripped from moist, decaying stumps, into the house from the forest. He was careful to keep them moist with wet moss or filter paper, and in the house he placed them under a bell-jar so that they would not dry out and kill the delicate mycelium. Ordinarily the light would last several days or weeks, when the plant would die—for want of food material, in all probability.

He next attempted to transfer small portions of the mycelium from the wood to a richer and more lasting medium, and, with that end in view, he prepared flasks and covered dishes in which were placed portions of sterilized nutrient media, as bread, rice, gelatin, and a sort of broth made from plums, as suggested by Brefeld in some previous work. In some cases agar was used as a base for the plum broth. With a fine needle bits of the mycelium were transferred to the various dishes, and these were then covered so as to exclude so far as possible other fungi, as Penicillium.

Such contamination did occur in many jars, as would be expected, but in several he found the mycelium growing well in pure culture and stretching its creeping arms around, through and over the bread or growing out flat on the surface of the more solid media. One culture was of *Agaricus melleus,* and the growing tips were white, but when the strands were well formed they became light brown to dark brown wherever they were exposed to a fair supply of air. Such parts of the growth as came into contact with glass and such parts as were covered by the fluid that lay on the bottom of the glass remained white. During the growth of the plant small drops of a brownish fluid were exuded from the surface and, these becoming confluent, they formed larger drops that fell to the bottom of the dish and accumulated a considerable amount of the fluid.

Only those portions of the mycelium that were above the fluid showed the power to produce light; and the very young white portions also seemed unable to shine. The period during which a culture could shine was considerable, sometimes over a month. And then a portion of mycelium could be transferred to a new flask with bread and it would grow and go on shining. One mycelium was thus kept in a luminous condition for several months.

This mycelium was, as has been said, the plant of *Agaricus melleus,* and it came to the fruiting condition, as can be seen in Fig. 7. Here we see a flask with some bread on its bottom covered

with the strands of the mycelium. Growing up from this are three sporophores or fruit-bodies that are not light producing in this form.

Another mycelium was found by Molisch and cultivated in the same way for long periods. This plant never came to fructification, and so he never learned its real species. He called it mycelium X and its identity is probably lost forever because even if we find one like it and secure fruit-bodies we can never be sure that it is this particular one. Mycelium X was much lighter in color than *Agaricus*, being, at its darkest, of a light-brown shade.

This form was the most favorable for study because of a greater ease of culture and the superior intensity of its light. One culture in a large flask on sterile bread grew and lighted for over a year and a half. The light was brightest in young, strong cultures, where it was white, according to Molisch.

The light of all known luminous mycelia appears to be intracellular. Molisch concludes this from the fact that the luminous material would not rub off on the hand. He also showed that it was not bacterial in nature.

We have noted that the light of fungi showed some differences in color and intensity. Those differences have been observed with the eye and have, to some extent, been measured by physical apparatus, but by far too little has been done in this direction.

Two observers, Achard in 1783 and Murray in 1827, studied the light of fungi and made the mistake of saying that they were single colored. Achard stated that he came to this conclusion because the light would not pass through colored glasses and also would not break up into constituent rays when passed through a prism. Others have since proved that it would do both these things. Murray was using another form of organic light (insect) in which the spectral extent was still larger, and in consequence his mistake was the greater.

In 1884 Ludwig took up the physical study of the light emanating from fungi, and studied it in four forms of these plants, as well as in the bacterium, *Micrococcus pflugeri,* which he secured from some meat and which he considered as identical with the bacteria found on most sea-fish that have begun to decay. The fungus forms he studied were *Trametes pini* (?), *Agaricus melleus, Xylaria hypoxylon,* and *Collybia tuberosa.*

The researches were conducted by means of the Sorby-Brown-

ing micro-spectral apparatus and comparison prisms and measuring apparatus. Also the light was tested by means of glasses colored in blue, green, orange, violet, and red. The spectral qualities of these glasses were determined previously.

FIG. 7.

Glass flask with sterilized bread on its bottom and the mycelium of *Agaricus melleus* growing over and through the bread. Three fruit-bodies have budded out from the mycelium. (After Molisch.)

Examination of *Trametes pini:* Ludwig brought active bits of the mycelium of this form into a dark chamber and found that it was not very bright. The brightest portion was put under the micro-spectral apparatus and upon looking through the objective only a blue shimmer was seen. After his eyes had become ac-

customed to the dark for two hours (!) the outline of the spectral band became visible, and a number of dark lines and one broad dark band crossed it. By turning the prism through which the light from the mycelium came the spectrum of the organic light was brought into a parallel comparison with the spectrum from a ray of light that came from a lighted test candle. This comparison showed that the spectrum of the mycelium light began in the clear blue, from which it extended into the ultra-violet. The dark lines lay in the clear blue, while the broad band was placed in the violet.

The red and the violet glasses allowed no rays to pass through from the mycelium, while they readily allowed part of a weak ray of daylight to be seen through them. A very little of the mycelium light passed through the dark-blue glass, a little more through the orange, and a much larger proportion through the green. This light appeared to come unobstructed through the light-blue test-glass, which same glass cut down the candle-light strongly.

Agaricus melleus was next investigated and with more exact results than, it appears to the writer, in the preceding case. Ludwig describes it as a whitish light with a trace of green. The spectrum was a continuous one (it seemed remarkable that in the preceding case of *Trametes pini* the spectrum should contain dark lines and a dark band) and reached from about 45 to 76 of the Sorby-Browning scale. This was determined by comparison with the spectrum of daylight (later day or evening), by comparison with the absorption spectra of several substances, and measurements with the measuring apparatus, as well as with the various colored glasses.

The transparency of the weak daylight was best through the glasses in the following order: orange, red, violet, blue, and green. That of the *Agaricus melleus* was, on the other hand, as follows: orange, green (fairly good), violet (weak), blue (still weaker), red (not transparent). He noted here that the green glass narrowed the spectrum considerably. This might be expected of any colored glass that cut out any of the wave-lengths produced by the mycelium. Much the same results were attained with the other two fungi, *Xylaria hypoxylon* and *Collybia tuberosa,* and I will merely indicate the principal results.

Trametes pini: Color of light not given. Extent in spectrum, from clear blue to ultra-violet. Exact boundaries not given.

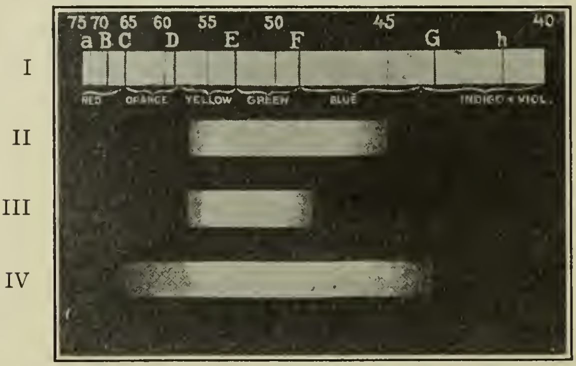
Agaricus melleus: Color of light, whitish tinged with green. Extent of spectrum, from 45 to 76 in Sorby-Browning scale.

Xylaria hypoxylon: Color of light, greenish gold to green. Extent of spectrum, from 55 to 85 in Sorby-Browning scale. One can distinguish the two fungi in the dark both by the eye (color of light) and smell.

Collybia tuberosa: Light weak and could not be accurately placed.

The determination of the color of fungus light by the eye appears to be difficult. Thus Molisch called the light of *Agaricus melleus* and *Mycelium X* " faint white "; according to Kutscher,

FIG. 8.



Four spectral bands shown in comparison: I. Spectrum of sunlight. II. Spectrum of *Bacterium phosphorens.* III. Spectrum of mycelium X. IV. Spectrum of *Pyrophorus noctiucens.* (I-III, after Molisch; IV, after Langley and Very.)

when growing in wood it was " bluish-white." And Molisch called it, under the same circumstances, " bluish-green." Ludwig saw it as " light-blue," and Hartig, " glowing-white." Brefeld described it in forest growth as " whitish tinged with blue." Molisch saw an *Agaricus* from Java as blue-green. Gardner saw the " Flor de Coco " in Brazil as pale-green. Rumph spoke of *Agaricus igneus* as " bluish." According to Tulasne, *Agaricus olearius* shone " like phosphorus." The most pronounced verdict of green color comes from Lanterers, who describes the light of *Panus incandescens* as " emerald green," while Henning speaks of the light from two forms, *Collybium tuberosa* and *Locellina illuminans,* as plain " green."

While allowing for carelessness in defining color and for differences of retinal power to distinguish some shades, it seems fair to state that there are considerable differences in the color of the various fungi. More extended work should be done with accurate instruments in the field, and differences of color should not be stated so emphatically when observed with the naked eye unless a direct comparison side by side has been made.

Altogether it may be said with Molisch that there are slight differences in color and that the fungus light presents a spectral range that is the shortest yet measured, beginning toward the red at the same point that the spectrum of bacterial light does and extending towards the blue a much less distance than that light does. It is continuous and contains no lines as yet determined (see Fig. 8).

(*To be continued.*)

Solution of Smoke, Fume, and Dust Problems by Electrical Precipitation. L. BRADLEY. (*Metallurgical and Chemical Engineering*, vol. xiii, No. 15, December 1, 1915.)—It is well understood that the smoke, fume, and dust constantly discharged into the atmosphere in the operation of various industries are not only a menace to health and comfort in their vicinity, but also entail a waste of valuable material which would yield a handsome return if collected. The electrical precipitation process developed by Dr. Frederick G. Cottrell has yielded notable results in the solution of this problem. The process consists essentially in compelling the dust- or vapor-laden products to pass between electrodes maintained at a high potential difference.

By this means the particles in suspension become electrified and are attracted and held to such electrodes arranged in the path of the escaping gases. A successful application of the process has been made in an electrolytic copper refining plant near New York City where gold, silver, and other materials are collected as slimes. When these latter are treated in a furnace for the recovery of the gold and silver, a considerable part of these materials was lost as fume. These valuable fumes are now being collected by electrical precipitation, and, whereas previously the actual losses were several thousand dollars per annum, they do not now exceed $300 per annum.

The German Potassium Salts. A. GRADENWITZ. (*Scientific American Supplement,* vol. lxxx, No. 2084, December 11, 1915.)—The remarkable standing of German agriculture is due to the assistance of a highly-developed science rather than to the excellence of the soil or the advantages of a privileged climate. In fact, Nature, in Germany, has, in both respects, been rather sparing with her bounties. However, the country possesses one treasure of inestimable value, viz., its deposits of potassium salts, which are not found in any appreciable amounts outside of Germany and on which the agriculture of the world is to some degree dependent.

The German potassium salt deposits were formed by gradual settling in a branch of the ocean which once covered a large portion of northern Germany. When the saturation of the brine had reached a certain degree, the least soluble salts, carbonate and sulphate of lime, were the first to separate, while the sodium, potassium, and magnesium salts still remained in solution, there being a continued, though not regular, water supply from the ocean. As evaporation advanced, the main part of the rock salt separated in its turn, thus becoming the mighty base of all present potash beds. The mother-lye now contained, besides sodium compounds, only magnesium and potassium salts, which concentrated the more rapidly as the high temperatures and violent storms stimulated evaporation. Magnesium sulphate was the first to separate in what is known as the Kieserite region, above which the potash at last settled in a double salt of potassium and magnesium chlorides, mixed with some sodium salt, known as carnallite, constitutes the main component of the more important potassium salt deposits, and is found in inexhaustible amounts throughout northern Germany.

The potassium salt deposits eventually became covered with an air- and water-tight coating of fine clay, on which a layer of substantial sand and clay settled in the course of time. Great variety was, however, produced in the composition and arrangement of the salt beds by the water entering through any fissures. Apart from carnallite, there are some other potassium minerals of importance to the agriculturist, viz., hard salt, produced from carnallite by the action of water washing away the magnesium chloride; sylvanite, another product of carnallite, freed also of its kieserite and kainite, in connection with which only magnesium chloride has been washed out.

The carnallite, kainite, hard salt, and sylvanite are blasted out of the deposits, 1000 to 3000 feet in depth, by means of explosives, after which they are taken to the surface in cages and ground to fine powders immediately suitable for use as fertilizers. From carnallite these are, however, made by artificial processes—dissolving, crystallizing, and drying—special fertilizers containing a high percentage of potash, of which a 40 per cent. potassium salt is of growing importance for German agriculture.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

The Annual Report of the National Bureau of Standards has just been issued and contains material of great technical interest to the industries and to the scientific laboratories. The Bureau's activities may be partially judged by the fact that forty-six new publications were issued during the year, not including revised editions of technical papers and circulars. The new publications included five numbers of the *Bulletin of the Bureau of Standards,* which completes the eleventh volume of the scientific papers. There were also issued 25 scientific papers, 10 new technologic papers, 8 new circulars, and 3 miscellaneous publications.

The following new circulars were issued during the year: "Units of Weight and Measure, Definitions and Tables of Equivalents," "Standard Methods of Gas Testing," "Safety Rules to be Observed in the Operation and Maintenance of Electrical Equipment and Lines," "National Standard Hose Couplings and Fittings for Public Fire Service," "Measurement of Time and Tests of Timepieces," "Regulation of Electrotyping Solutions," "Composition, Properties, and Testing of Printing Inks," and "Proposed National Electrical Safety Code."

The following scientific papers were issued: "Testing of Potentiometers," "Emissivity of Metals and Oxides—I, Nickel Oxide (NiO) in the Range 600° to 1300° C.," "Adjustments of the Thomson Bridge in the Measurement of Very Low Resistances," "Quantitative Experiments in Radiotelegraphic Transmission," "Measurements on Standards of Radiation in Absolute Value," "Experimental Study of the Koepsel Permeameter," "Various Modifications of Bismuth-Silver Thermopiles Having a Continuous Absorbing Surface," "Combustion Calorimeter and Heats of Combustion of Cane Sugar, Benzoic Acid, and Naphthalene," "Specific Heat of Copper in the Interval 0° to 50° C., with a Note on Vacuum-jacketed Calorimeters," "Equilibrium in the System: Lead Acetate, Lead Oxide, and Water at 25°," "Watthour Meter Method of Testing Instrument Transformers,"

* Communicated by the Director.

"Insulating Properties of Solid Dielectrics," "Direct-reading Instrument for Measuring the Logarithmic Decrement and Wavelength of Electromagnetic Waves," "Electrical Resistance and Critical Ranges of Pure Iron," "Absorption, Reflection, and Dispersion Constants of Quartz," "Characteristic Equations of Tungsten Filament Lamps and Their Application in Heterochromatic Photometry," "Vibration Electrometer," "Studies on the Silver Voltameter," "Wheatstone Bridge for Resistance Thermometry," "Emissivity of Metals and Oxides—II, Measurements with the Micro-pyrometer," "Emissivity of Metals and Oxides —III, Total Emissivity of Platinum and the Relation Between Total Emissivity and Resistivity," "Comparison of Stellar Radiometers and Radiometric Measurements on 110 Stars," "Temperature Coefficient of Magnetic Permeability Within the Working Range," "Methods of Measuring the Inductances of Low-resistance Standards," and "Emissivity of Metals and Oxides—IV, Iron Oxide."

The following technologic papers were issued: "Industrial Gas Calorimetry," "Iodine Number of Linseed and Petroleum Oils," "Observations on Finishing Temperatures and Properties of Rails," "Analysis of Printing Inks," "Veritas Firing Rings," "Lead Acetate Test for Hydrogen Sulphide in Gas," "Standardization of No. 200 Cement Sieves," "Hydration of Portland Cement," "Study of the Atterberg Plasticity Method," and "Study of Some Recent Methods for the Determination of Total Sulphur in Rubber."

The following miscellaneous publications were issued: "Annual Report of the Director for the Fiscal Year Ended June 30, 1914," "Ninth Annual Conference on the Weights and Measures of the United States," and "Decennial Index to the Bulletin of the Bureau of Standards."

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. It involves primarily the investigation of the scientific principles underlying the tests, the study of existing methods, and the development of new standard tests of determinate accuracy. For each test a reasonable fee is charged, except when made for the National or State Governments.

During the fiscal year 1915 the Bureau made 116,204 tests and inspected 1,861,439 incandescent lamps at various factories for

other departments of the Government. Of the total tests, 105,992 were for the Government and 10,212 for the public. The testing was distributed as follows, according to nature of tests: Length measures, 949; mass, 7,529; capacity, 2,230; temperature, 15,734; hydrometry, 2,224; miscellaneous, 153; optical, 1,500; time, 28; electrical, 1,223; photometry, 3,506; chemical, 11,471; engineering (miscellaneous), 878; engineering (instruments), 367; structural materials, 60,989; paper and textiles, 7,359; metallurgical, 64.

FUSIBLE TIN BOILER PLUGS.

An investigation has been completed and prepared for publication on the failure and deterioration of fusible tin boiler plugs. This safety device for preventing boiler explosions is widely used in stationary and locomotive boilers and is required on the marine boilers on all steamboats coming under the jurisdiction of the Steamboat-Inspection Service, which Service brought the matter to the Bureau's attention through the failure of a plug to operate on the steamer *Jefferson,* causing loss of life. Some 1,200 plugs, both used and new, were examined, and this investigation has shown that, although pure tin is called for in the specifications, it often is not furnished by the manufacturer. It appears that only 0.3 per cent. zinc as impurity is sufficient to eventually cause the complete oxidation of the tin filling, thus rendering the plug dangerous, whereas strictly pure tin plugs will remain sound. Several of the specifications now in force are shown to be inadequate. It would probably be well to license a limited number of manufacturers of fusible boiler plugs whose product could be controlled by Federal inspection, and not permit promiscuous manufacture. At present the Steamboat-Inspection Service submits to this Bureau sample plugs from new manufacturers.

PROPERTIES AND STANDARD TEST SPECIMENS OF BRONZES.

The results of the investigation, undertaken at the suggestion of the American Institute of Metals, on the variations in foundry practice as influencing the properties of standard test specimens of the zinc bronze, known as Government bronze of composition 88 copper, 10 tin, 2 zinc, are embodied in a forthcoming technologic paper. The Bureau also has assisted in the preparation of the specifications for this bronze in coöperation with the American Society for Testing Materials. An extension of this work is out-

lined, consisting in the intercomparison of the properties of such specimens prepared from the same ingot metal, but by different foundries, according to a definite and uniform plan of procedure. This will afford information as to variations which may be expected in meeting specifications.

A metallographic examination has also been made, and the results are ready for publication, of the samples of zinc bronze (88 Cu, 10 Sn, 2 Zn) prepared at the Bureau by various methods. It would appear from this investigation that the presence and distribution of oxides in the casting is the predominating factor determining its quality.

This bronze has also been studied to determine its microstructural changes accompanying annealing. The results, which will be published shortly, show that the bronzes are very different in their behavior from steel and show no recrystallization or "grain refining" unless they have been previously cold worked, as by rolling or hammering.

RADIATION FROM METALS AND OXIDES.

The radiation intensities characteristic of the several metals and oxides, or their monochromatic and total emissivities, are of considerable metallurgical and pyrometric importance. The work described in last year's report on "The Emissivity of Nickel Oxide" has since been issued as Scientific Paper No. 224.

The same methods have been applied to iron oxide and published in Scientific Paper No. 249. Iron oxide in the spectral region $\lambda = 0.65\ \mu$ is almost "black," having an emissivity varying from 0.98 to 0.92 in the range 800° to 1200° C. The total emissivity increases from 0.85 at 500° C. to 0.89 at 1200° C. The corrections to be applied to optical and total radiation pyrometers when sighted on iron oxide are as follows:

	500° C.	600° C.	700° C	800° C.	900° C.	1000° C.	1100° C.	1200° C
Optical pyrometer......	0	0	0	+ 1	+ 2	+ 4	+ 6	+10
Radiation pyrometer ...	+30	+30	+35	+35	+40	+40	+45	....

The micropyrometer (see Scientific Paper No. 198) has also been adapted to the measurement of the monochromatic radiation of metals and oxides, it being possible to take observations rapidly and over a large temperature range on a quantity as small as

0.01 mg. presenting a surface of 0.25 mm.[2] The results of observations on 23 metals and 12 oxides have been published in Scientific Paper No. 242, showing that, in general, there is no temperature coefficient of emissivity and that for several metals, including platinum, there is a discontinuity in radiation at the melting point. This would render the Violle unit of light, based on platinum brightness at its melting point, a variable standard.

THE QUALITY OF PLATINUM WARE.

The thermoelectric method of classifying platinum ware, described in the last year's report, has been supplemented by measurements on the loss of weight of platinum on heating, with the object of determining the specifications and best composition for platinum ware, such as crucibles, which are subject to loss of weight on heating; a phenomenon which is very troublesome to the analytical chemist and which reduces the accuracy of his results. This investigation, which was undertaken at the suggestion of the American Chemical Society, afforded incidentally an opportunity, through the many samples examined, to form an estimate of the purity of high-grade platinum ware on the American market. Thus, of 164 samples examined, including a wide variety of objects, 43 pieces contained an equivalent iridium content of less than 0.5 per cent. and 110 less than 2 per cent. iridium. The loss of weight on heating for iron-free crucibles ranged from 0.71 mg. to 2.96 mg. per 100 cm.^{2} and per hour at 1200°, the greater losses being for crucibles containing iridium and the lesser with those containing rhodium. From the thermoelectric measurements of purity, combined with a microscopic examination, the probable loss of weight for any platinum crucible can be predicted with sufficient accuracy for analytical purposes. It is suggested, for highest grade crucibles, that iron-free platinum containing 3 to 5 per cent. rhodium be specified. This thermoelectric examination of platinum purity is now a regular Bureau test; also the Bureau's advice has been sought by several departments of the Government and other large users of platinum concerning purchases under this test.

CAUSES OF FAILURES OF RAILWAY MATERIALS.

In conjunction with the engineering and chemical divisions a comprehensive series of investigations of the causes of failure of railway materials has been undertaken, including some of the

fundamental problems in the manufacture, design, and properties of rails, wheels, tires, and axles, as related to their failure in service.

During the past year considerable necessary equipment has been assembled and a start made on several problems, including sound-ingot research, rail-finishing temperatures, transverse fissures in rails, properties of cast iron, thermal analysis, and metallographic methods of examination.

A very important event in this connection was a meeting held at the Bureau, May 22, 1915, attended by the technical representatives of 24 railway systems, at which the work of the Bureau on railway materials was discussed and a plan of cordial coöperation inaugurated, including the furnishing by the railways of statistics of failures and material for examination. It is believed that by thus working in coöperation with the railroads and gaining the benefits of their varied and extensive experience and technical advice, more rapid and efficient progress in the solution of the problems of the causes of failure of railway material will be made. The advantages of a centralized experimental laboratory which also has access to the material in service are manifest.

CAUSES OF FAILURE IN CAR WHEELS.

A study of car wheels is projected in view of the fact that they constitute one of the principal causes of railway accidents, and there are many matters of uncertainty as to best practice in manufacture and design. There are, for example, over 20,000,000 "chilled cast-iron" wheels in use in the United States and they are interchangeable from one railway to another, so that specifications should be rigid and uniform. Some of the items to be studied are statistics, foundry practice, mixtures used in manufacture, effect of sulphur on properties, braking and internal strains, strength of and best design, properties of hot cast iron, soaking pit practice, and relation of combined carbon to annealing. A beginning has been made on the last item.

TRANSVERSE FISSURES IN RAILS.

The problem which the railway conference of May 22, 1915, considered the most urgent is the determination of the causes of "transverse fissures," a hidden defect or split in the rail which often makes its occurrence evident only by the rupture of the rail

by a train. A series of questions on this subject have been submitted to practically all the railroads in the United States, asking for their experience, data and samples, and for suggestions as to methods of attack. The replies which are being received will be a most valuable guide in orienting this investigation, which will involve work in the laboratory, mill, and service, including trials of artificial production of such fissures by several methods, metallographic and chemical surveys of rails containing fissures compared with sound rails, examination of rails which have withstood long, severe service, and the effects of mill practice, including internal strains, gagging, and the completion of the chemical reactions across the rail section as influenced by manufacture. It is also hoped to have the coöperation of the optics division in the determination of the variation of expansion coefficient across the rail section.

FINISHING TEMPERATURES OF RAILS.

The survey of American practice regarding the finishing temperatures and properties of rails, mentioned in last year's report, was presented before the American Institute of Mining Engineers and has been published as Technologic Paper No. 38. The subject of finishing temperatures is one of the greatest importance in rail manufacture, and the discussion of the subject was participated in by several of the most prominent authorities in the country; and this discussion brought out a general confession of ignorance of many matters connected with the relation of methods of manufacture to the resulting properties of rails. It is hoped to be able to aid in the solution of some of these outstanding uncertainties. In Technologic Paper No. 38, the "shrinkage clause" in rail specifications such as those of the American Society for Testing Materials (defining the finishing temperatures by the shrinkage of the rail) was shown not to fulfil the intended requirements of its framers in limiting the temperature to slightly above the recalescence point. The rail committee of the American Society for Testing Materials presented a report concluding "there is lacking anything which points to such decided differences in the quality of rails rolled at varying temperatures as theoretical considerations have led some of us to expect." The society has instructed its rail committee to coöperate with the Bureau in a further investigation of this important matter.

It is also proposed to study several allied questions, including the relation of rail section to the temperature distribution on cooling, and the relation of the latter to the completeness of the chemical reactions, internal stresses, and metallographic transformation for different sections and compositions of rails.

SOUND INGOT RESEARCH.

The use of only sound steel ingots for the manufacture of rails and other structures, on which the safety of the public depends, is a matter of the greatest importance. With the coöperation of several steel manufacturers, the Bureau has been enabled to compare the behavior and properties of several types of ingot, including the Hadfield form, consisting in (1) piping steel, (2) cast large end up, (3) suitable sink head with (4) air blast on charcoal and slag. This method produces an ingot, 90 per cent. of which is physically and chemically sound. The results of this investigation, including also an examination of rails rolled from some of these ingots, were presented before the American Institute of Mining Engineers and also before the British Iron and Steel Institute. Opportunity has also been offered for a further study of this type of ingot by the Pennsylvania Railroad, which is to have rolled into rails 100 tons of Hadfield ingots, to be studied in detail by the Bureau.

Arrangements are also being made to study other processes of manufacture of sound ingots, such as the compression process of Mr. B. Talbot, of Middlesborough, England, and the "hot-top" ingots of the Cambria Steel Company, together with an examination of the effects of such ingredients as vanadium and titanium.

It is believed that an impartial study by the Bureau of the methods of manufacture of steel ingots, blooms, rails, and similar products will be helpful in stimulating an improvement in manufacturing methods and should result in more rigid specifications being enforced for those products the use of which involves life hazard.

TEST INGOT INVESTIGATION.

A matter of very great practical importance in the buying and selling of steel, involving acceptance or rejection of the material under specifications, is the determination of its analysis. The usual practice is to take for analysis a "test ingot" from the ladle

before casting and assume this to be representative of the finished product. These test ingots vary greatly, however, in shape and size and quality, and it seemed desirable to endeavor to standardize this practice.

The study has been continued during the past year with the coöperation of the American Society for Testing Materials. Data have been collected regarding American practice in the matter of the shape and size of such ingots, methods of sampling, etc. Seventeen of the leading steel companies have coöperated in the work by furnishing sample ingots of various grades of metal. This first series examined represents ingots poured directly; that is, without the addition of aluminium, silicon, or other substances for rendering the metal compact and free from blowholes. Later the influence of such additions will be considered.

Fifty-five ingots have been examined up to date. This examination, so far, has been entirely metallographic, including the mapping out of the regions of segregation of sulphur (as an index of the segregation in general) and the determination of the presence of included "scale," oxides, etc., in the porous metal. Careful chemical surveys of selected types will supplement and confirm this work. Up to the present the investigation seems to warrant the conclusion that shape and size of the ladle ingots are minor factors and that the investigation of the subject of additions to the metal upon pouring to render the ingot sound and free from holes is the most satisfactory solution of the problem.

This work should be extended eventually by a comparison of "test ingot" analysis with that of the finished products. It would appear that, at least for certain classes of materials, such as rails, the "test ingot" method of analysis should be rejected in favor of the analysis of the finished product.

FOREIGN RAILWAY SPECIFICATIONS.

A technological paper has been prepared on foreign railway specifications for rails, wheels, axles, and tires. This material was collected with the aid of the Department of State from the Governments or railway administrations of Austria-Hungary, Belgium, France, Germany, Great Britain, Holland, Italy, Russia, and Sweden. The circular contains a comparison and discussion of these specifications, including a summary of accident statistics, as well as translations of the foreign text of the specifications

for rails, wheels, axles, and tires. It is expected the circular will be of interest to those responsible for and interested in the specifications for such railway material in the United States. In general, it may be stated that the foreign railway materials, such as rails, wheels, tires, and axles, appear to perform the duty imposed upon them in a more adequate manner than is the case in America.

FAILURE OF STRUCTURAL BRASSES.

A comprehensive study of the causes of failure in service of structural brasses and bronzes has been undertaken by the Bureau. The costly experience of the New York Board of Water Supply on its Catskill Aqueduct project as well as the failures of bronze in the Minneapolis filter plant and elsewhere, the former of which has been widely advertised, raised the questions whether the bronzes used for such structural purposes were suitable for the purposes for which they were designed, whether the specifications were inadequate, or the methods of manufacture at fault. There appears to be a very serious lack of reliable data upon which to draw up specifications for this type of material and the ordinary tests do not usually give an indication of the true permanency of such bronzes which may easily be spoiled in manufacture.

The Bureau has had the coöperation of a number of brass and bronze manufacturers who have furnished material made, as suggested by the Bureau, in several ways; and the Bureau has been able to obtain failed material from several sources, including the New York water board, city of Minneapolis, and the Navy Department.

The relation of the presence of internal stresses to methods of manufacture and subsequent heat treatment have been carried out for numerous samples from various sources. It would appear that the presence of these internal stresses, sometimes associated with corrosion, is largely responsible for failure. It has also been shown these stresses can be removed by annealing, without serious detriment to the physical properties. The effects of corrosion on stressed brasses is also to be studied. There is in this problem of defining the just limitations of non-ferrous alloys for structural and other purposes a wide field of research.

A preliminary account of the work already done is being prepared for publication.

PREPARATION OF PURE IRON AND IRON CARBON ALLOYS.

It is shown that previous work on the iron-carbon diagram is unsatisfactory because of the great variation in the materials used. It was, therefore, thought necessary to produce a series of alloys of great purity to form the basis of a redetermination of the diagram at the Bureau of Standards. The general method consisted in melting electrolytic iron with sugar carbon in magnesia crucibles. The electrolytic iron was prepared from ingot iron anodes in a chloride bath with or without the use of porous cups. The operation of melting the iron with carbon gave great trouble at first because the ingots obtained were full of blowholes and contained considerable quantities of impurities. These difficulties were overcome by melting in a vacuum furnace and making crucibles of especially pure magnesia, made and calcined at the Bureau of Standards. A satisfactory procedure was finally worked out and a series of alloys prepared of the composition $Fe + C = 99.96$ per cent.

THE IRON-CARBON EQUILIBRIUM.

During the early part of 1914 work on the thermal analysis of pure iron was completed and the thermal study of the iron-carbon series was started. A large number of alloys ranging from 0.02 to 1.8 per cent. carbon were made up and observations taken by the inverse rate and derived differential methods for some 250 heating and cooling curves. These observations have all been plotted and a study of the effect of rate on the location of the critical points has been started. Upon the completion of this work and a study of the effect of decarbonization, the results will be ready for publication. Work on this problem has been delayed or interrupted by the preparation and installation of exhibits for the San Francisco Exposition and by testing.

DETERMINATION AND DISTRIBUTION OF CARBON IN STEELS AND IRONS.

The improvement of analytical methods in metallurgical chemistry are of great economic significance as well as of scientific interest. Two methods for the rapid determination of carbon in steels have been devised, one by direct combustion in oxygen at high temperatures, a preliminary account of which has been published; the other by a conductivity titration method, which is in preparation.

The relation of the amount of graphite to the heat treatment of cast iron is of importance in the manufacture of chilled cast-iron wheels. Some preliminary work has been done in coöperation with one of the wheel manufacturers.

THE PHYSICAL PROPERTIES OF PURE IRON AND COPPER.

The pure iron made at the Bureau is being studied for several of its physical properties. Scientific Paper No. 236 has been published describing the experiments on the electrical resistance and temperature coefficient of pure iron between 0° and 950° C. These experiments, carried out with a precision of 1 in 300,000, demonstrate the non-existence of transformations below 757° C., show the Ac_3 and Ar_3 transformations to begin at the same temperature 894° C. and extend over 25°, and accompanied by a decrease in resistance on heating and an increase on cooling through the A_3 transformation. The A_2 transformation, the interpretation of which is still in dispute, is evidenced by a very sharp cusp at 757° C. in the temperature coefficient curve, or by an inflexion in the resistance curve.

Exact measurements have been taken of the resistance of copper in the interval 0° to 100° C. with the object of detecting allotropic changes which have been reported by Prof. E. Cohen, of Utrecht.

MELTING POINTS OF STEELS AND REFRACTORY ELEMENTS.

The determination of the melting points of a considerable number of steels of practical importance has been undertaken and is nearly complete. Also the melting points have been determined, by means of the micropyrometer, of practically all of the refractory chemical elements. It is hoped to be able to publish these results shortly.

A TEST OF A SURFACE COMBUSTION FURNACE.

In view of the fact that the surface combustion process appeared to offer many advantages for high-temperature laboratory furnaces, in which the Bureau is interested, it was decided to submit a crucible furnace of this type to a thorough test. For the purpose, the furnace was equipped with meters on the gas and air lines, and with a chimney to permit the collection of flue-gas samples. In several runs the mixture proportions were maintained constant while varying the rate of gas consumption. Tempera-

tures were read by a Holburn-Kurlbaum optical pyrometer. The highest temperature reached was 1675°, at which point the muffle failed. The test established that complete combustion could be attained without excess air, that the best air-gas ratio was 5.5, and that a 20 per cent. excess of air caused a lowering of furnace temperature of 100°. An account of this test, which is the first of its kind, is in course of preparation.

NOMENCLATURE OF NONFERROUS ALLOYS.

A paper which evoked considerable discussion was presented before the American Institute of Metals on the " Progress in the Nomenclature of Alloys." There is great need for systematizing the naming of complex alloys and of their constituents. The coining of new names and the use of proper names is being discouraged, and it is probable that from the several suggestions which have been made a rational system of nomenclature may be worked out which meets the needs of the foundryman on the one hand and is correct scientifically on the other hand. The Bureau of Standards in coöperation with the American Institute of Metals is considering the matter, and it has been hoped to bring about uniformity for the English-speaking countries through the coöperation of the British Institute of Metals and its allied societies; and possibly, at least as concerns some of the fundamental principles, international agreement may be reached through the active advocacy of the subject by the editor of the International Journal for Metallography.

INVESTIGATION OF MOULDING SANDS.

In coöperation with the American Institute of Metals, the Bureau has begun an investigation of the properties and methods of testing molding sands, with the object of finding out the characteristic qualities of such sands as have proved serviceable and endeavoring to put on a better scientific basis the classification of molding sands. A preliminary report will be presented at the fall meeting of the American Institute of Metals.

CO-OPERATION WITH MANUFACTURERS ON NONFERROUS METALS.

A very important feature of the work in metals at the Bureau has been the coöperation with manufacturers on non-ferrous metals, including representatives of the American Institute of

Metals, the American Chemical Society, the American Institute of Mining Engineers, the American Society for Testing Materials, and the American Electrochemical Society. Two well-attended meetings have been held during the past year at the Bureau, which has greatly aided in suggesting and mapping out lines of work, securing typical materials or samples, and obtaining the aid and benefit of the experience of many manufacturers for several problems in which the Bureau is interested.

SYSTEMATIC INVESTIGATION OF THE PROPERTIES OF METALS.

Knowledge of the properties of even the more commonly used metals and alloys, especially at high temperatures, is very meagre, and their determination requires, in many cases, elaborate and costly experimental arrangements and considerable skill.

Pulp from Cotton Stalks. Anon. (*Scientific American,* vol. cxiii, No. 23, December 4, 1915.)—A use for cotton stalks, heretofore considered valueless and a troublesome feature incidental to the growing of cotton, has finally been developed, and, although the industry is only beginning, it promises to be an important one. Already a plant is being erected at Greenwood, Miss., which will be devoted to the preparation of pulp from cotton stalks. The cotton stalks, after being converted into pulp, are to be used in the place of wood pulp in paper making. Because of the stronger fibres of the cotton-stalk pulp, it is said that paper manufactured from the cheaper pulp is considerably stronger than that produced from the usual wood pulp. The use of cotton pulp is not limited to the making of paper; it is also applicable to the production of gun cotton and other cellulose materials.

Wet Collodion. Anon. (*British Journal of Photography,* vol. lxii, No. 2898, November 19, 1915.)—There are, perhaps, relatively few workers in the photographic art, accustomed to the convenience and undoubtedly excellent results of the dry plate or film, who realize what an important place the old wet collodion process still holds in commercial photography. The description in this article of the practice of the process, with its multiplicity of detail and minutiæ of manipulation, would indeed discourage any one for whom the modern method will suffice. But for process-work, lantern slides, and other subjects requiring the maximum precision in the distribution of contrasts, the wet-plate process, with all its difficulties, retains an undisputed field.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE STRIPPING OF GELATINE DRY PLATES.[1]

By S. M. Furnald.

THE following method is recommended:

A solution is made as follows:

4 per cent. sodium fluoride	2 parts
Formaline (40 per cent. formaldehyde)	1 part

The portion of film to be stripped is first cut around with a knife. The solution of fluoride and formaline may be flowed over the plate or applied with a camel's-hair brush to the portion of film to be stripped. The film will become loosened from the glass in about one minute, and may then be easily lifted by applying over it a piece of dampened paper, lifting carefully one corner and stripping the paper and film away together.

If reversal of the film is required, it is easily transferred to a second piece of paper and from that to the final support.

The glass on which the film is to be laid should be perfectly clean and flowed with a 5 per cent. solution of gum arabic. A little glycerine added to the gum solution tends to improve the condition of the stripped film, which otherwise becomes rather over-dry and horny, owing to the formaline.

With small portions of film there is very little danger of distortion or tearing, but if the plate is first bathed for ten minutes in formaline before applying the stripping solution, the film will strip equally well and is tougher and less liable to distortion.

When stripping large films the plate may first be flowed with

Collodion	30 c.c.
Glycerine	2 c.c.

and, so soon as the collodion film has become set, flowed or immersed in the fluoride and formaline solution; the time required for loosening the film may be slightly longer, but this method gives a tough, rubbery film, considerably stronger than film stripped without the collodion coating.

* Communicated by the Director.

[1] Communication No. 34 from the Laboratory.

Grinding Wheels. W. C. GOLD. (*Metal Industry,* vol. 13, No. 11, November, 1915.)—Previous to the advent of the grinding wheel made from artificial or natural abrasives, manufacturers were dependent upon the natural quarried grindstone. In 1890 emery wheels only were manufactured. The abrasive employed was Turkish emery, now used only for polishing purposes. In 1892 emery from the island of Naxos (Grecian Archipelago) came into use, and for some years proved the best material for the manufacture of grinding wheels.

The first artificial abrasive was "carborundum" or carbide of silicon, manufactured by the Carborundum Company, of Niagara Falls, N. Y., which began business in 1891. Under the name of "aloxite" this firm placed upon the market an artificial corundum in 1909. The Norton Company, of Worcester, Mass., in 1906, abandoned the use of emery entirely and adopted its new artificial abrasive, which it calls "alundum." "Boro-carbone" is made in southern France, where an immense deposit of bauxite exists, and is shipped to the Abrasive Materials Company, of Philadelphia, and there manufactured into grinding wheels and bricks. This product was placed upon the market in 1913.

There are to-day thirty plants, large and small, manufacturing grinding wheels in the United States and Canada. Emery, though still used to some extent, has been largely supplanted by the artificial abrasives, and the carbide of silicons and aluminous oxides of clay or bauxite have come into extended use. So indispensable have grinding wheels become in the realm of manufacturing that many consumers have stated that they would be low-priced if sold at list prices only.

Copper Plating as Used for Purposes Other than Ornamental. E. G. LOVERING. (*The Metal Industry,* vol. 13, No. 11, November, 1915.)—The automobile trade in general is installing copper-plating plants for the electro-deposition of copper on automobile parts, such as cam shafts, gears, etc., previous to heat treatment and hardening. The blank gears and forged cam shafts are sent to the copper-plating department and given a heavy deposit of copper. After they have been machined, they are hardened by the cyanide hardening process, which does not penetrate the (unmachined) parts which have a deposit of copper, but leaves them soft, while only the exposed parts, such as the cam faces and gear teeth, are hardened.

Parts that require a driving fit are given a deposit of from 0.001 to 0.004 inch in thickness and then driven into place, thus making a fit that cannot become loose by vibration. Wire wheels, spokes, radiators, and other parts are given a coating of copper previous to painting and enamelling operations. The bath employed is a combined cleaning and plating bath into which the objects may be immersed without any preliminary cleaning after the machining or other manufacturing operations.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, December 15, 1915.*)

Hall of The Franklin Institute,
Philadelphia, December 15, 1915.

President Walton Clark *in the Chair.*

Additions to membership since last report, 19.

Mr. George H. Clamer, Chairman of the Committee on Science and the Arts, reported the condition of its work.

The following nominations were made for officers and managers to be voted for at the annual election to be held January 19, 1916:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Henry Howson; (to serve two years), Louis E. Levy.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, Robert S. Perry, and E. H. Sanborn; (to serve two years), Kern Dodge; (to serve one year), William C. Wetherill.

The Chairman appointed the following members to act as tellers of the election: Messrs. W. N. Jennings, George S. Cullen, and Henry F. Colvin.

Mr. Louis E. Levy, on behalf of the Board of Managers, presented a minute on the death of Vice-President James Mapes Dodge.*

Dr. Alexander Crever Abbott, Director of the Laboratory of Hygiene, University of Pennsylvania, Philadelphia, presented the paper of the evening on "The Transmissibility of Diseases and the Public Health." The manifold channels of transmission of diseases, as well as the methods used, in some cases, in the destruction of the morbific agents of disease, and in others for their utilization to a good end, were fully described. Tables and statistics were presented which indicated that pure water, coupled with better drainage systems, had materially reduced typhoid fever, small-pox, diphtheria, and many other diseases in the large cities. Diseases transmitted by milk and other foodstuffs were also given consideration, as was the rôle of the house-fly and mosquito as carriers of bacterial infections. The subject was fully illustrated by numerous lantern slides.

Mr. Levy remarked that the meetings of the Institute were usually signalized by important presentations on subjects of a more or less technological nature which, while of great significance to all workers in the

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* See page 151.

field of the applied sciences and of interest to all who realize the importance of these applications in our modern industrial life, could be fully appreciated only by those engaged in the special branch of science under discussion. But the subject of Dr. Abbott's lecture came home to us all. It dealt with a matter of prime importance to every individual, the life, health, and happiness of every member of the community. The Institute was very fortunate in receiving this highly valuable addition to its present course of lectures. Mr. Levy moved that the thanks of the Institute be therefore tendered the lecturer. This motion, largely seconded, was unanimously adopted, and the President thereupon conveyed the thanks of the Institute to Dr. Abbott.

Adjourned. R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, December 1, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 1, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for final action:

No. 2617.—Permutit. Elliott Cresson Medal to Dr. Robert Gans, of Pankow, near Berlin, Germany, adopted.

No. 2626.—Dorr's Hydrometallurgical Apparatus. Final action on this report was deferred until next meeting.

No. 2635.—Northrup's High Temperature Investigations. Final action on this report was deferred until a later date.

No. 2636.—Lenker's L-E-Vation Rod. Edward Longstreth Medal of Merit to Will G. Lenker, of Sunbury, Pa., adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, December 2, 1915, at 8 o'clock P.M. Mr. H. A. Hornor, of The Franklin Institute, and Mr. J. H. Tracy, of the

American Institute of Electrical Engineers, presided jointly. The minutes of the previous meeting were read and approved as published.

John D. Ball, E.E., of the Consulting Engineering Department of the General Electric Company, Schenectady, N. Y., delivered an address on "Magnetic Investigations of Iron and Steel." It was demonstrated that the failure of sheet steel to follow the Steinmetz hysteresis law at high inductions is due to the presence of impurities, such as scale, which in themselves follow the law but have different constants. The results of tests on scale-free material were reported, and the chemical, physical, and magnetic properties of the scale were discussed. A short *résumé* was given of the results of tests made with unsymmetrical loops, where the mean induction is other than zero, as in apparatus used in rectified circuits, inductor alternators, etc. The lecture was illustrated with lantern slides. After a discussion of the paper by Dr. Hoadley and others, a vote of thanks was extended to the lecturer, and the meeting adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, December 9, 1915, at 8 P.M. Mr. George R. Henderson, president of the Section, occupied the chair.

Professor W. F. M. Goss, D.Eng., Dean of the College of Engineering, University of Illinois, Urbana, Ill., Chief Engineer of the Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals, Chicago, Ill., delivered a lecture, entitled "Smoke as a Source of Atmospheric Pollution." Professor Goss gave a brief account of an elaborate study of smoke and of atmospheric pollution in the city of Chicago, including an analysis of the amount of fuel consumed in the several different classes of service, such as in power plants, in locomotives, in manufacturing industries, and in domestic heating; of the character and amount of smoke arising from these different services; of the effects of smoke, and of the possibilities presented by the existing state of the art whereby the smoke of a modern American city may be abated.

After an interesting discussion, a rising vote of thanks was extended the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

(*Stated Meeting, Board of Managers, December 8, 1915.*)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. F. J. LEMAISTRE, Ridley Park, Pennsylvania.

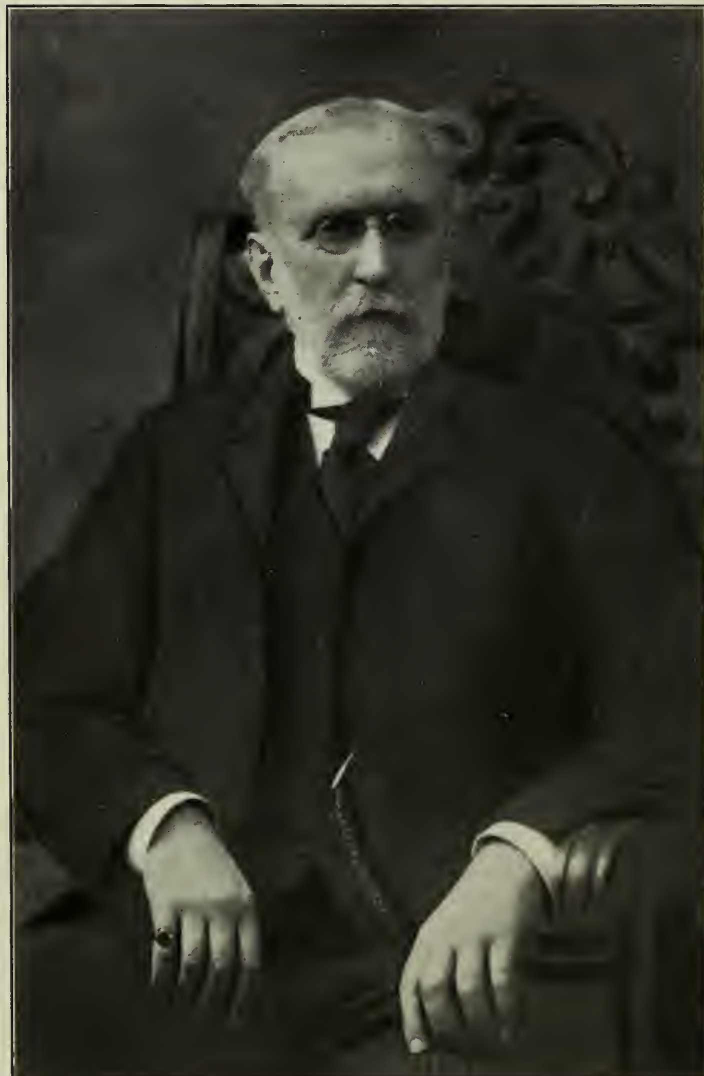
DR. THOMAS D. COPE, Randal Morgan Laboratory, University of Pennsylvania, Philadelphia, Pa.

NON-RESIDENT.

DR. RAYMOND F. BACON, Director, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.
MR. J. T. BAKER, Phillipsburg, N. J.
MR. JOSEPH BANCROFT, Wilmington, Del.
MR. HOLGER V. BERG, Newport, Del.
MR. CHARLES S. BERNARD, No. 2, Allentown, Pa.
PROF. WILLIAM FREAR, State College, Pa.
DR. F. W. FRERICHS, Herf & Frerichs Chemical Company, St. Louis, Mo.
DR. HAROLD H. FRIES, 92 Reade Street, New York City, N. Y.
DR. WILLIAM J. GIES, 437 West Fifty-ninth Street, New York City, N. Y.
DR. MOSES GOMBERG, 725 Oxford Road, Ann Arbor, Mich.
MR. HARRY KIPPENBERG, care of Merck & Company, Rahway, N. J.
MR. JOHN D. PENNOCK, 2002 West Genesee Street, Syracuse, N. Y.
DR. WALTER F. RITTMAN, care of U. S. Bureau of Mines, Pittsburgh, Pa.
MR. C. P. SCHLICKE, 440 Washington Street, New York City, N. Y.
DR. HUGO SCHWEITZER, 410 Riverside Drive, New York City, N. Y.
DR. JOKICHI TAKAMINE, Equitable Building, New York City, N. Y.
MR. CHARLES A. WEST, 14 Fulton Street, Boston, Mass.

CHANGES OF ADDRESS.

MR. GEORGE S. BARROWS, 275 West Exchange Street, Providence, R. I.
MR. R. B. CARNAHAN, JR., 710 South Main Street, Middletown, Ohio.
DR. DAVID T. DAY, Adams Building, 1333 F Street, N. W., Washington, D. C.
MR. BYRON E. ELDRED, Commercial Research Company, Goodyear Building, Long Island City, N. Y.
MR. A. E. GIBBS, care of Pennsylvania Salt Manufacturing Company, Widener Building, Philadelphia, Pa.
MR. WEBB L. GIBBS, 7734 South Shore Road, Chicago, Ill.
MR. CLARENCE A. HALL, 1935 Chestnut Street, Philadelphia, Pa.
MR. GEORGE R. HENDERSON, 1321 Walnut Street, Philadelphia, Pa.
MR. RICHARD HOWSON, 401 Woodlawn Avenue, Wayne, Delaware County, Pa.
MR. JOHN J. KOHLER, Allenwood, Union County, Devitt's Camp, Pa.
MR. CHARLES W. MCMEEKIN, 1270 Pine Street, San Francisco, Cal.
DR. EUGENE L. MAINES, 799 Putnam Avenue, Brooklyn, N. Y.
MR. ROBERT S. REDFIELD, Wayne, Pa.
MR. W. F. THORNTON, Mechanicsburg, R. R. No. 2, Pa.
DR. L. M. TOLMAN, 1831 Wesley Avenue, Evanston, Ill.
MR. CHARLES S. VADNER, 22½ West Seventh South Street, Salt Lake City, Utah.
MR. HENRY W. WILSON, 605 Franklin Building, 133 South Twelfth Street, Philadelphia, Pa.



John T. Morris

NECROLOGY.

John Thompson Morris was born July 12, 1847, and died August 15, 1915.

The death of John Thompson Morris, a life member of The Franklin Institute, was the subject of a special minute adopted by the Board of Managers of the Institute at its meeting on October 13, 1915, and published in the November issue of the JOURNAL. The following memoir is supplementary to that publication:

John Thompson Morris was the son of Isaac Paschall Morris and Rebecca Thompson Morris, of Philadelphia. He was educated at Haverford College. He became a member of the firm of I. P. Morris & Co., builders of steam engines, boilers, and machinery, of which his father was the head. His father died in 1869, and when, in 1876, the firm was incorporated as the I. P. Morris Company, John T. Morris became its president, and continued in that position until the absorption of the company by the Cramp Shipbuilding Company in 1891.

Mr. Morris was a leading spirit in the financial, the civic, and the cultural activities of Philadelphia. He was especially interested in numismatics as a branch of history and archæology, and his researches on coinage, ancient and modern, gained him wide recognition as an authority on the subject. He became a member of the Numismatic and Antiquarian Society in 1891, its vice-president in 1897, and served as its president from 1899 to 1904, when he declined reëlection, but consented to resume the vice-presidency, and held that position to the time of his death. But his active interests extended in many other directions. He was a vice-president of the Fairmount Park Art Association, a trustee of the Pennsylvania Museum and School of Industrial Art, a member of the American Philosophical Society and of its Finance Committee, a life member and Councillor of the Historical Society of Pennsylvania, a life member of the City Parks Association, one of the overseers of the William Penn High School, president of the Board of Trustees of The Franklin Institute, chairman of the Committee on Wissahickon Park Extension, for a time a member of the Board of Directors of Haverford College, and a leading member of the Union League of Philadelphia. After his retirement from business he devoted his time and thought to these institutions, and gave liberally of his means to promote their aims.

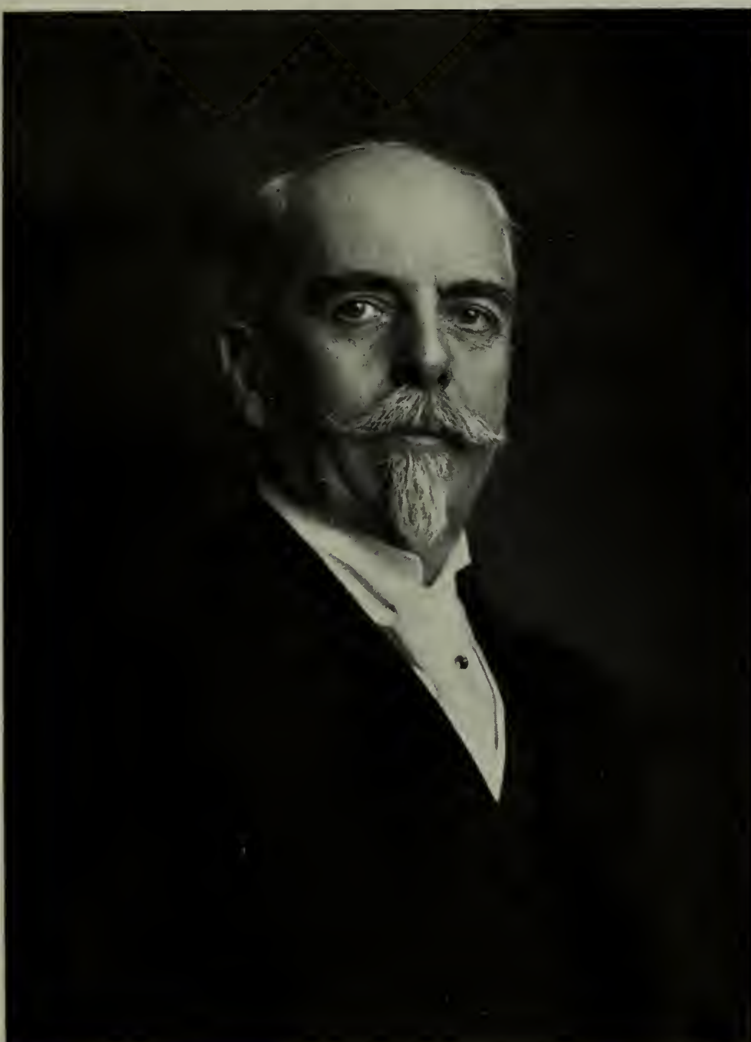
He became a member of the Board of Directors of the Philadelphia Contributionship for the Insurance of Houses from Fire on December 18, 1895, and was elected chairman of the Board on September 25, 1905. He was a member of the Board of Managers of the Philadelphia Saving Fund Society.

His kindly nature greatly endeared him to his personal friends, and his broad sympathies, his public spirit, and unostentatious liberality commanded the high esteem of his contemporaries in many ranks of the community.

James Mapes Dodge, master mechanical engineer, inventor, authoritative technologist, head of a great industrial organization, and leading publicist, died at his home in Philadelphia, December 4, 1915. He was born at Waverly, N. J., June 30, 1852, a son of William and Mary Mapes Dodge, the former a prominent member of the Bar in New York City, and the latter a gifted authoress, widely known as editress of *St. Nicholas Magazine,* and whose father, Professor James J. Mapes, was a noted chemist and scientist.

Young Dodge's education, begun at home, was furthered at the Newark Academy, and continued through a three years' course at Cornell University and a year at Rutgers College, at which latter institution he made a special study of chemistry under the late Professor George H. Cook, State Geologist of New Jersey. His first practical experience was gained at the Morgan Iron Works, in New York City, but he soon found more congenial employment in the shipbuilding works of John Roach & Sons at Chester, Pa., where his ingenuity and marked ability were given recognition through his rapid advancement from the position of a journeyman to that of foreman and later to that of superintendent of construction. In 1876, after three years at the shipyard, Mr. Dodge entered into partnership with E. T. Copeland for the manufacture of mining machinery in New York City, but two years later he turned from this to join with William D. Ewart and his associates in Chicago for the development of Ewart's invention of the link-belt chain and its commercial exploitation. In this undertaking he found opportunity for the exercise of his genius as inventor and as organizer. He became superintendent of the Indianapolis Malleable Iron Works, where the link chain was being manufactured, and under his direction the methods of its production were improved, new forms of the link chain developed, new uses found for it, and the field for its application rapidly widened out. Possibilities of power transmission and of elevating and conveying machinery unthought of until then were realized, and a new and important industry was thus created. This accomplished, Mr. Dodge, in 1884, returned to the East and, in partnership with Edward H. Burr, established in Philadelphia the firm of Burr & Dodge, as representatives of the Ewart Manufacturing Company of Indianapolis, for the further exploitation of the link-belt enterprise. The business grew apace, and four years after its establishment was reorganized as a corporation in the form of the Link-Belt Engineering Company.

Here Mr. Dodge's conceptions of systematized production were carried out in detail. Under his direction a thoroughly-specialized engineering staff was organized, the nature and qualities of the materials to be dealt with were scientifically studied, and special appliances and new forms of link-belt conveyors were invented to meet new requirements as they arose. Mechanisms for dealing with materials in quantities of comparatively small amount were followed by others of greater size, and have been developed to the capacity of handling 1000 tons per hour, and, from meeting increasing exigencies by the ordinary means of additional separate machines, the work progressed to the production of specially-designed apparatus under guarantee of handling the materials in question, whether raw or finished products, in the efficient and economic manner projected. In all this development Mr. Dodge was the



James Mapes Dodge

moving spirit and his was the guiding hand. He it was who designed the form and arrangement of the links and attachments of all the various sizes and kinds of link-belting used to-day throughout the world, and such was the thoroughness of his work that his devices have not as yet been found possible of improvement.

His genius as an inventor found new expression in the method of handling of coal on a large scale which he conceived in 1889, after a thoroughgoing study of the elements of the problem. This invention, as original in conception as it was bold in design, effects the storing of coal in piles of conical shape, and its reloading from those piles, in a manner at once so simple and effective as to have left it without a rival in its field. The Dodge system of conveying coal into and out of storage has resulted in a reduction of the cost of the handling from between 30 and 40 cents per ton to less than 5 cents, a saving which is realized on the fully 5,000,000 tons handled by this system annually. The importance of this invention as a great labor-saving device was recognized by The Franklin Institute in 1904 through the assignment of its highest award, the Elliott Cresson Gold Medal, to the inventor.

Among other of Mr. Dodge's important inventions may be noted the design and construction of the Renold Silent Chain, by which that appliance was made practically available. His invention of the bushed joint as applied in this type of power-transmitting medium opened for it a field in which it had long been a desideratum and in which its usefulness has steadily become more widely recognized.

Fertility of invention and mechanical ingenuity are but rarely combined with a high order of business ability. Yet such a combination was exemplified by Mr. Dodge. As an inventor he had the distinction of being among the few mentioned in the report of the Patent Office as having been granted a full hundred patents and over, and as a man of affairs he won a place of equal distinction as the organizer and executive of a great industrial corporation. From 1892 he was the president and active manager of two eminently successful engineering and manufacturing enterprises, the Link-Belt Engineering Company and the Dodge Coal Storage Company, the latter afterwards known as the J. M. Dodge Company, and he was chairman of the Board of Directors of the Link-Belt Company, elected in 1906, when that corporation was formed through the merger of the Link-Belt Engineering Company of Philadelphia, the Link-Belt Machinery Company of Chicago, and the Ewart Manufacturing Company of Indianapolis, with Mr. Charles Piez as its president. His record in these relations is that of an energetic and far-seeing director of business affairs.

Mr. Dodge had, furthermore, the enviable distinction of being a large employer of men, with whom, through many years, his relations had always been those of a fraternal and, in many instances, of a paternal order. Strikes and labor disputes were unknown under his direction, his earnest personal interest in the welfare and advancement of his employees, his working associates, winning for him their respectful admiration and even affectionate regard. He was a very model in this as in so many other of his ways, exemplifying in this respect the potent influence of a spirit of justice and good-will.

Mr. Dodge early took an active interest in the scientific study of industrial efficiency originated by his friend and neighbor, Frederick Winslow Taylor, and was the first to introduce the Taylor system of shop management in actual practice. His example was followed in a wide circle of large employers of labor, and his leadership in this direction, which aimed toward the development of initiative, ambition, and a sense of responsibility in every member of the working force, was universally acknowledged.

He made numerous contributions to the literature of this subject, presenting at the Dartmouth Conference on Scientific Management in 1911 a review of his experiences with this system and of its benefits to the wage earners, in whose behalf his interest in the matter had primarily been enlisted. The same idea formed the theme of his discourse before the German Society of Engineers and the American Society of Mechanical Engineers in joint meeting at Leipzig in 1913, and at many other similar conferences. He favored the system principally as a means of removing an underlying cause of industrial unrest through its efficacy in increasing the capacity, and thereby advancing the status, of the wage earners, and under his intelligent direction these purposes were fully achieved.

In yet other ways did Mr. Dodge manifest his altruistic spirit. For over thirty years, in the midst of all his pre-occupations, he took an abiding interest and an active part in the promotion of every movement that tended to civic betterment and in the support of every agency working to that end. He never held public office, but gave public service of a high order as member of the Citizens' Committee of Seventy and as president of the Public Service Committee of One Hundred in Philadelphia, where his unremitting devotion to the cause of good government was recognized by all.

Besides his numerous articles in the periodical press on various technological matters, he was the author of books on "Coal Storage," on "Holmes's Lubricant Bearing," and on "Rope Power Transmission." He received the honorary degree of Doctor of Science from Stevens Institute of Technology, was past-president of the American Institute of Mechanical Engineers, vice-president of The Franklin Institute, a trustee of the Philadelphia School of Design, and member of the leading civic and social clubs in Philadelphia and of similar organizations elsewhere.

With all his impressive qualities as a gifted mechanician, a forceful executive, and a thoughtfully considerate employer, James Mapes Dodge combined yet another characteristic, that of a genial liveliness which distinguished him at once in every circle of society. His humorous pleasantries were ever fresh and seemingly inexhaustible, his drollery was never-failing, his ready wit ever combined with penetrating wisdom, and his animated countenance expressive of both. As a story teller he was simply inimitable and a constant source of merriment and glee. Mark Twain once said that "Jim" Dodge was the best story teller that he had ever known, and in this he but described in fewest words one of Mr. Dodge's most striking traits. His optimism was fairly inspiring, and the kindliness of his nature such as would find an especial pleasure in having all the children of his neighborhood join with his own in the delights of a skating pond which he built on the grounds of his home in Germantown.

Mr. Dodge is survived by his wife and their four children, two sons and two daughters, one of the former, Kern Dodge, connected with the Link-Belt Company at Philadelphia as consulting engineer, and the other, Carl Dodge, with the allied corporation in Chicago.

The passing away of James Mapes Dodge has left a vacancy that will be sorely felt in many widely-scattered centres of activity, but nowhere more so than at The Franklin Institute, where he had made his intellectual home for many years past and where he will be missed for many a year to come. So thought the members of the Institute at the meeting where the following minute was adopted:

> In sorrowful recognition of the great loss which The Franklin Institute has suffered through the death of its distinguished member and Vice-President,
>
> DR. JAMES MAPES DODGE,
>
> the Board of Managers of the Institute, at its meeting on Wednesday, December 8, unanimously resolved to present to the Institute, at its stated meeting on December 15, a record of this recognition for inclusion in the minutes of the Institute.
>
> As a leader in his chosen field of mechanical engineering, as a writer of acknowledged authority on the technology of his profession, as a promoter of scientific efficiency and harmonious collaboration in all the ranges of industrial activity, as a man of large affairs and great achievements, James Mapes Dodge commanded an unbounded measure at once of admiration and respect.
>
> But it was not alone as an engineer, an author, and a captain of industry that this man excelled. He was a ready and untiring helper in all that made for progress in the world's work, a moving spirit in all that made for social betterment and civic righteousness. His life was the expression of a high ideal, and all his ways were good.
>
> An earnest co-worker in the activities of The Franklin Institute through over thirty years, he had been one of its life members since 1892 and its vice-president and *ex-officio* member of its Board of Managers since 1903. In that capacity he gave to the last a yeoman's service to the work in hand, furthering its aims and purposes in every needed way. Combining the qualities of a blithesome temperament and a kindly nature with all the best traits of a forceful character, James Mapes Dodge exerted in the direction of the Institute affairs, as in those of the community at large, an influence that was often determinative of far-reaching results and which has left the impress of his rare personality as a permanent memento of his activity.

L. E. L.

Richard W. Gilpin was born in West Chester, Pa., and died at Cape May, N. J., on June 21, 1915.

He was educated in the Episcopal Academy of Philadelphia. His fondness for scientific pursuits, especially in the electrical field, induced him to early enter the employ of the Weston Electrical Instrument Company, where he spent about four years. Later he became connected with the United States Lighting Company, one of the first concerns devoted especially to house and street lighting by electricity. In 1895 he established a consulting engineering office in Philadelphia. Here he found an ample field for his efforts, which included the power, lighting, and heating equipments of many of the most important buildings or groups of buildings in Philadelphia.

Mr. Gilpin joined The Franklin Institute in 1887, and became a life member in 1891. He was appointed a member of the Committee on Library in 1903, and in 1904 was elected to the Committee on Science and the Arts.

He was a member of numerous clubs and associations, social and technical, and for many years was actively interested in civic affairs.

Washington Atlee Burpee was born at Sheffield, New Brunswick, Canada, April 5, 1858, and died at Doylestown, Pa., November 26, 1915.

Mr. Burpee was educated in the Friends Central School, Philadelphia, and the University of Pennsylvania. He began his business career as a seedsman in 1876, and two years later organized the present firm, W. Atlee Burpee & Company. He was director of a number of banks, trust companies, hospitals, and charitable organizations, and a member of the leading horticultural societies of the world. He was elected to membership in The Franklin Institute in 1905.

William Hunter, Reading Terminal, Philadelphia, Pa.

CORRESPONDENCE.

UNIVERSITY OF ILLINOIS. URBANA, ILLINOIS,
December 14, 1915.

THE FRANKLIN INSTITUTE,
Dr. R. B. Owens, Secretary,
15 South Seventh Street,
Philadelphia, Pennsylvania.

DEAR SIR:

I am sending you herewith several copies of a circular concerning the Research Fellowships which are available in the Engineering Experiment Station of the University of Illinois. There will be five vacancies to be filled at the close of the current academic year. I shall greatly appreciate your courtesy if you will give such publicity as may be convenient to the opportunities afforded by these fellowships.

Believe me,

Very truly yours

[Signed] W. F. M. GOSS,
Dean of the College of Engineering.

RESEARCH FELLOWSHIPS
in the
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS
Urbana-Champaign, Illinois

To extend and strengthen the field of its graduate work in engineering, the University of Illinois has since 1907 maintained ten Research Fellowships in the Engineering Experiment Station. These fellowships, for each of which there is an annual stipend of $500.00, are open to graduates of approved American and foreign universities and technical schools. Appointments to these fellowships are made and must be accepted for two consecutive collegiate years, at the expiration of which period, if all requirements have been met, the Master's degree will be granted. Not more than half of the time of the Research Fellows is required in connection with the work of the department to which they are assigned, the remainder of the time being available for graduate study.

Nominations to fellowships, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of February. These nominations are made within the month of February by the Station Staff, subject to the approval of the Faculty of the Graduate School and the President of the University. Appointments are made in March, and they take effect the first day of the following September. Vacancies may be filled by similar nominations and appointments at other times.

Nominations to these fellowships are based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following their undergraduate work.

The Engineering Experiment Station, an organization within the College of Engineering, was established in 1903 for the purpose of carrying on investigations in the various branches of engineering, and for the study of problems of importance to engineers and to the manufacturing and industrial interests of the State. Research work may be undertaken in architecture, architectural engineering, chemistry, civil engineering, electrical engineering, mechanical engineering, mining engineering, municipal and sanitary engineering, physics, railway engineering, and in theoretical and applied mechanics.

The work of the Station is closely related to that of the College of Engineering, and the Heads of Departments in the College constitute the administrative Station Staff. Investigations are carried on by the members of the staff and other members of the instructional force of the College of Engineering, by special investigators employed by the Station, and by the Research Fellows.

Additional information may be obtained by addressing

THE DIRECTOR,
Engineering Experiment Station,
University of Illinois, Urbana, Illinois.

Note: By action of the Board of Trustees on March 9, 1915, four additional Research Fellowships were created in the Engineering Experiment Station, making fourteen in all.

COLUMBUS, OHIO, December 13, 1915.

THE FRANKLIN INSTITUTE,
Philadelphia,
Penna.

GENTLEMEN:

I would be glad to have you state in your Journal that the editorial offices of the *Journal of the American Pharmaceutical Association* have been moved from Columbus, Ohio, to care of Philadelphia Drug Exchange, Bourse Building, Philadelphia, Pa.

Respectfully,

[Signed] E. G. EBERLE,
Editor.

LIBRARY NOTES.

PURCHASES.

CUNNINGHAM, E.—Principles of Relativity. 1914.
ELIOT, C. W., and STORER, F. H.—Elementary Manual of Chemistry. 1880.
FORSYTH, A. R.—Theory of Functions of Two Complex Variables. 1914.
Incorporated Institution of Automobile Engineers.—Proceedings, vols. 1–8. 1906–1914.
Institute of Metals.—Journal, vols. 1–13. 1909–1915.
LANGE, K. R.—By-products of Coal-gas Manufacture. 1915.
LEVY, S. I.—The Rare Earths. 1915.
Mineral Industry: Its Statistics, Technology and Trade, vol. 23. 1914.
RASCH, EWALD.—Electric Arc Phenomena. 1913.
SEARLES, WILLIAM H., and IVES, H. C.—Field Engineering. 1915.
Thomas Publishing Co.—Thomas's Register of American Manufactures, 7th edition. 1915.
TOWNSEND, J. S.—Electricity in Gases. 1915.
VEGA, GEORG.—Thesaurus Logarithmorum Completus. 1794.

GIFTS.

The Works of the Honourable Robert Boyle, in five volumes, to which is prefixed the life of the author by Thomas Birch, M.A. and F.R.S., London. Printed for A. Millar, 1744. Five volumes, folded plates, portrait, folio. (From Dr. Charles F. Himes.)
American Iron and Steel Institute, Annual Statistical Report, 1914. Philadelphia, 1915. (From the Institute.)
American Railway Tool Foremen's Association, Year Book, 1915. Chicago, no date. (From the Association.)
American Society for Testing Materials, Proceedings, vol. xv. Philadelphia, 1915. (From the Society.)

Association of American Portland Cement Manufacturers, Publications on Concrete and Cement. Philadelphia, 1912 to 1915. (From the Association.)

Baltimore and Ohio Railroad Company, Eighty-ninth Annual Report. Baltimore, 1915. (From the Company.)

Buffalo Foundry and Machine Company, Catalogue of Vacuum Apparatus. Buffalo, no date. (From the Company.)

Canada Department of Mines, Memoir 34, The Devonian of Southwestern Ontario: Electrothermic Smelting of Iron Ores in Sweden. Ottawa, 1915. (From the Department.)

Chicago Association of Commerce, Report of the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals. Chicago, 1915. (From the Association.)

Chicago, Rock Island and Pacific Railway Company, Thirty-fifth Annual Report. Chicago, 1915. (From the Company.)

Dahlgren, Ulric, Structure and Polarity of the Electric Motor Nerve-cell in Torpedoes: Origin of the Electric Tissues of Gymnarchus Niloticus. Washington, 1914 and 1915. (From the Author.)

Dahlgren, Ulric, and C. F. Silvester, The Electric Organ of the Stargazer, Astroscopus. Jena, 1906. (From Prof. Ulric Dahlgren.)

DeLaval Steam Turbine Company, Catalogue F of Centrifugal Blowers and Compressors. Trenton, N. J., 1915. (From the Company.)

Denison University, Annual Catalogues, 1912–13 and 1913–14. Granville, Ohio, 1913 and 1914. (From the University.)

Dorman, Long and Company, Pocket Companion, Containing Useful Information and Tables Pertaining to the Use of Steel, for the Use of Engineers, Architects and Builders. Middlesborough, England, 1915. (From the Company.)

Eighth International Congress of Applied Chemistry, Original Communications, vols. 1 to 29. Washington and New York, 1912. (From Mr. Pedro G. Salom.)

Fay, Spofford and Thorndike, Report of Watuppa Ponds and Quequechan River Commission, City of Fall River, 1915. Boston, no date. (From Messrs. Fay, Spofford and Thorndike.)

Finland Industristyrelsen, Meddelanden, sextitredje haftet; Handtverksstatistik, B, 1913; Industristatistik, A, 1913; Arbetsstatistik, A, 1912, B, 1913. Helsingfors, 1915. (From the Industristyrelsen.)

Hughes, James G., Jr., A Peculiar Structure in the Electroplax of the Stargazer, Astroscopus Guttatus. Philadelphia, 1915. (From Prof. Ulric Dahlgren.)

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Jefferson Physical Laboratory of Harvard University, Contributions, 1913–1914, vol. xi. Cambridge, no date. (From the Laboratory.)

John Crerar Library, A list of Books on the History of Industry and Industrial Arts. Chicago, 1915. (From the Library.)

Lynn Commissioner of Water and Water Works, Annual Report, 1914. Lynn, Mass., 1915. (From the Commissioner.)

Manchester Association of Engineers, Transactions, 1914–1915. Manchester, 1915. (From the Association.)

National Academy of Sciences, Memoirs, vol. xiii. Washington, 1915. (From the Academy.)

National Association of Railway Commissioners, Proceedings, 1889–1903 and 1908–1911. Washington, 1889 to 1911. (From Mr. Wm. H. Connolly, Secretary.)

New South Wales Department of Mines, Mineral Resources No. 18, The Canbelego, Budgery, and Budgerygar Mines, part ii. Sydney, 1915. (From the Department.)

New York City Board of Water Supply, Ninth Annual Report. New York, no date. (From the Board.)

New York Public Service Commission for the First District, Proceedings, vol. 9. New York City, N. Y., no date. (From the Commission.)

New York Public Service Commission for the Second District, Eighth Annual Report, part 2. Albany, 1915. (From the Commission.)

New Zealand Geological Survey Branch, Bulletin No. 17, The Geology and Mineral Resources of the Buller-Mokihinui Subdivision. Wellington, 1915. (From the Survey.)

New Zealand Minister of Mines, Statement, 1914. Wellington, 1915. (From the Minister of Mines.)

Ohio State University, Catalogue, 1914–15. Columbus, 1915. (From the University.)

Ontario Bureau of Mines, Annual Report. Toronto, 1915. (From the Bureau.)

Pennsylvania Bureau of Industrial Statistics, 1914. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Health, Report, 1912. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Insurance Commissioner, Annual Report, part i, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Secretary of Internal Affairs, Annual Report, parts ii, iii, iv. Harrisburg, 1914. (From the State Librarian.)

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Union Twist Drill Company, Catalogue G of Machine Tools. Athol, Mass., no date. (From the Company.)

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Yale University, President's Report, 1914–1915; Treasurer's Report, 1914–1915. New Haven, 1915. (From the University.)

BOOK NOTICES.

UNITED STATES BUREAU OF MINES BULLETIN 98, Report of the Selby Smelter Commission, by J. A. Holmes, E. C. Franklin, R. A. Gould. Washington: Government Printing Office, 1915. 520 pages and index, 8vo. Price, $1.25.

This is one of the most interesting and valuable contributions to industrial hygiene ever published. Unfortunately, space does not permit of more than a mere outline of the data. The Selby (Cal.) Smelter, treating ores containing much sulphur and notable amounts of lead and arsenic, was made defendant in a suit alleging injury to animals and plants over a rather wide area. After several years of litigation, the parties agreed to the appointment of several experts (as above), who present their final decision in the volume in review. They find that with the devices installed by the company no appreciable injury is done to life or property. Two points are worthy of special note. By the installation of an electrical system the "fume" (condensed vapor) of sulphuric acid is almost entirely eliminated from the stack-discharge, and the average daily output of sulphur dioxide is about 58 tons.

The text of the report unfortunately shows a considerable number of instances of carelessness of syntax and lack of good form so much in evidence, nowadays, in American scientific literature. An example is seen on the typographic map that accompanies the volume. A single correction is entered under the title "errata."

HENRY LEFFMANN.

CHEMICAL CONSTITUTION AND PHYSIOLOGICAL ACTION, by Doctor Leopold Spiegel. Translated, with additions, by C. Luedeking, Ph.D., and A. C. Boylston, A.M. New York: D. Van Nostrand Company, 1915. 155 pages, 12mo. Price, $1.25.

That the properties of bodies are dependent on their chemical composition seems a truism, yet but few except relative data have been obtained by research. The present work contains a large amount of information concisely expressed. About one-third of the book is devoted to inorganic compounds, and the remainder to organic, among which, of course, considerable attention is given to the newer remedies, commonly termed "coal-tar synthetics." A quotation from the "Résumé" may be given: "We have studied certain groupings which furnish a preliminary basis for certain effects. Then we have observed that, given these fundamental nuclei, the physiological action of the compounds may be varied . . . by the action of individual side-chains. Among those side-chains which seem to release the latent activity of the nucleus, we find those groups which also favor an increased chemical activity. The strikingly noticeable groups of this sort are the amino, hydroxyl, and carbonyl groups."

The translation is well done and the book is well printed. Numerous structural formulas are given. The absence of an index and of any explanation of the abbreviations of the names of journals and other references is to be regretted.

HENRY LEFFMANN.

BACTERIOLOGICAL METHODS IN FOOD AND DRUGS LABORATORIES, with an Introduction to Micro-chemical Methods, by Albert Schneider, M.D., Ph.D. Philadelphia: P. Blakiston's Son & Co., 1915. 277 pages and index, 87 illustrations and 6 full-page plates, 12mo. Price, $2.50.

This compact and handy volume contains a large amount of interesting and useful matter, including many of the most recent procedures. As the title indicates, the bulk of the book is devoted to bacteriologic methods, the descriptions of which are given on the assumption that the user is familiar with the general principles of bacteriology. Under the head of "Micro-chemical Color Reaction Tests" some very useful procedures are described, among which may be noted F. Emich's methods with cotton fibres impregnated with chemicals that enable the detection of minute amounts of the common, so-called, poisonous metals. This section is well worth the attention of the food analyst. The numerous illustrations add much to the value of the work, which deserves a place in the library of every worker in its field.

HENRY LEFFMANN.

HOW TO MAKE A TRANSFORMER FOR LOW PRESSURES, by F. E. Austin. Second edition. Hanover, N. H.: Published by the author. 17 pages, illustrations, 12mo. Price, 40 cents.

This book contains a clear account of the method of building an efficient step-down transformer for use on ordinary commercial currents. It is in the main, of course, adapted to young workers, and, as regards its subject matter and method of treatment, it affords an interesting contrast with the "Boy's Own Book" type of literature of half a century ago.

PUBLICATIONS RECEIVED.

A Treatise on Safety Engineering as Applied to Scaffolds. 354 pages, illustrations, plates, 8vo. Hartford, Conn., The Travelers Insurance Company, 1915. Price, $3.

South Carolina Geological and Economic Survey: Economic Paper No. 41, Proceedings of the Seventh Annual Drainage Convention of the North Carolina Drainage Association, held at Wilson, North Carolina, November 18 and 19, 1914. Compiled by Joseph Hyde Pratt, State Geologist, and Miss H. M. Berry, Secretary. 76 pages, 8vo. Raleigh, State Printers, 1915.

Ontario Bureau of Mines: Twenty-fourth Annual Report, 1915. Two parts, illustrations, plates, maps, 8vo. Toronto, King's Printer, 1915.

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Finding and Stopping Waste in Modern Boiler Rooms by the Use of the Cochrane Appliances for Accurately Measuring and Recording Boiler Feed, Condensate, Blow-off, Heating Returns, Cooling Water, etc. 68 pages, illustrations, 8vo. Philadelphia, Harrison Safety Boiler Works, 1915.

Establishing and Maintaining Boiler-room Economy, by George H. Gibson. (Reprinted from the *Journal of the Ohio Society of Mechanical, Electrical and Steam Engineers,* vol. 7, No. 2, June, 1915.) 8 pages, illustrations, 8vo.

Unique Hydraulic Power Plant at the Henry Ford Farms. M. A. REPLOGLE. (*Proceedings of the American Society of Mechanical Engineers,* New York, December 7 to 10, 1915.)—The hydraulic power plant recently constructed at the Henry Ford Farms contains two turbines with direct-connected electric generators designed to develop 85 horse-power each under 8 feet head at 110 revolutions per minute. At the site of the plant there were unusual flowage conditions, due in part to the high head of water at certain periods and in part to back water from the Great Lakes. These conditions were met and a uniform delivery of power secured through the adoption of an unusual feature in the installation of the turbines. This consists of the so-called turbine discharge accelerators built into the tail-race of each turbine; with these accelerators an added head effect is produced and the flow through the turbines increased.

The accelerator consists of a form of draft-tube into which the turbine discharges, and into which, also, water from the upper level is discharged through a feeder terminating in an annular casing surrounding the outlet of the discharge tube from the turbine. The water from the feeder increases the flow—accelerates the flow through the draft-tube. The advantages of this arrangement are that with an adequate volume of water available the power capacity can be practically doubled at the normal head and the normal speed maintained when the working head is less than 25 per cent. of the normal head with good efficiency.

CURRENT TOPICS.

The Electric Arc in Vapors and Gases at Reduced Pressures. W. A. Darrah. (*Metallurgical and Chemical Engineering,* vol. xiii, No. 15, December 1, 1915.)—Some very promising experiments in the development of a design of an arc lamp in which the large factors in the cost of operation of trimming and cleaning are eliminated have been described in a paper read before a joint meeting of the American Electrochemical Society and the Illuminating Engineering Society. These experiments had for their object the design of a lamp in which the supply of material for the arc did not come from the electrodes, but from a surrounding gas or vapor, and if, in passing through the arc, the vapor were not destroyed, to construct a lamp that would require no trimming or materially more attention than an incandescent lamp.

The lamp consists essentially of a glass bulb arc chamber, at the centre of which the arc is drawn between two tungsten electrodes about $^3/_{16}$ inch in diameter. The electrodes are partly surrounded with a refractory insulator designed to prevent the arc from moving far from the ends of the electrodes, as this allows the magnetic blow of the arc to continue to extend it and ultimately rupture the arc. The refractory insulator also assists in maintaining the electrodes at a high temperature, thus increasing the efficiency of the lamp and the stability of the arc. The upper electrode is fastened by means of a tungsten rod to an iron core, which is surrounded by a glass shell to protect the iron from corrosion, as the vapors used readily attack nearly all metals, except tungsten, platinum, gold, and a few other inert materials. A flexible tungsten spiral serves to conduct the current from the upper movable electrode to the upper seal.

The appearance of the arc is quite different from other commercial arc lamps. It is usually very stable, about $\frac{1}{8}$ inch in diameter, tubular in form, and varies from 2 to 5 inches in length with 110 volts direct current applied, the variations being due to differences in pressure, nature of the gases supplied, etc.

Regarding the efficiency secured, it is to be expected that this will vary widely with the nature and the condition of the vapors used, and actual results range from 1 watt per mean spherical candle-power to less than one-quarter of this value. This performance may be secured with a white light which closely resembles afternoon north-ray daylight. The vapor of titanium bromo-chloride is recorded as giving a high luminosity white light and a very stable arc.

A New High-efficiency Incandescent Lamp. E. A. Gimingham and S. R. Mullard. (*Journal of the Institution of Electrical Engineers,* vol. 54, No. 251, December 1, 1915.)—In 1913 experi-

ments were started in the lamp research laboratory of the Edison & Swan United Electric Light Company, at its Powders End works, with the object of making a lamp having the usual characteristic of the ordinary incandescent lamp, that is to say, as regards the shape and size of bulb, stem, and cap, but having as a source of light an arc between electrodes of tungsten or other suitable refractory conductor burning in an inert gas such as nitrogen or argon.

The lamp has three leading-in terminals. The two outer ones carry a U-shaped filament. The middle one carries an electrode, near the negative leg of the U, charged to a positive potential. From the experiments of Sir J. J. Thomson, Dr. Fleming, and others, it is well known that the filament in an incandescent lamp gives off a strong negative discharge, and if an additional electrode sealed adjacent to the filament be charged to a positive potential, a current passes between the filament and this electrode. In operation the current first passes through the ionized circuit, causing the filament to incandesce at a temperature sufficient to ionize the gas between it and the positive electrode. At first a small current flows in the gap between the free electrode and the filament, this current rapidly increasing until a cut-out is operated. This breaks the ionizer circuit and the arc is " struck."

As compared with carbon filament lamps (3.5 watts per candle-power) with an intrinsic brilliancy of about 375 candle-power per square inch, the metal-filament lamps giving 1000 candle-power per square inch, the intrinsic brilliancy of the new lamp at an efficiency of 0.5 watt per candle-power is approximately 10,000 candle-power per square inch. The color of the light may be made to vary from a bright yellow, when running at low efficiencies, to a very intense white light. The range of intrinsic brilliancy between their limits is approximately 400 to 30,000 candle-power per square inch. Lamps have been made with a life of 500 hours, and it is hoped that further experiment will make it possible to obtain a true half-watt lamp with a life of 800 hours. During life the average decrease in candle-power is about 10 per cent.

Thermal Reactions of Petroleum Hydrocarbons in the Vapor Phase. W. F. RITTMAN. (*The Journal of Industrial and Engineering Chemistry*, vol. 7, No. 11, November, 1915.)—One of the most widely studied and important chemical problems of the day is the thermal decomposition or " cracking " of petroleum hydrocarbons. The first experiments were conducted in connection with the problem of oil-gas production and were limited to such conditions as might apply in that field. In the present experiments it has been possible to learn facts of the greatest importance concerning liquid products of the cracking reaction, and, in addition, valuable information has been obtained regarding the course and mechanism of the process. The characteristic feature of these experiments is that cracking has been conducted in the vapor phase, the primary advantage of which

is that both temperature and pressure may be controlled separately and at will. The results at hand have led to the following conclusions with regard to the cracking reactions:

1. The nature, both physical and chemical, of an oil is of secondary importance, compared with the influence of temperature, time, and pressure, in controlling the products of the cracking reaction. Under like conditions approximately similar results have been obtained from five different oils, and it has seemed that the minor existing differences may as probably be due to variation in rate of reaction as to the actual formation of unlike equilibrium products.

2. From any oil it is possible to make any desired type of hydrocarbon by adjusting properly the conditions of treatment. (*a*) The most favorable conditions for gasoline production are on temperatures of about 500° and pressures higher than 6 atmospheres. (*b*) Low-boiling aromatic hydrocarbons are produced best at temperatures between 600° and 700°, with pressures above 4 atmospheres. (*c*) Higher temperatures favor the production of carbon and gas at the expense of the liquid reaction products.

3. The course of the cracking process is one of dehydrogenation.

4. The formation of aromatic compounds seems to occur in either of three ways: (*a*) The original oil may be decomposed to small molecule compounds of the acetylene series, which subsequently polymerize to form the larger aromatic nuclei. (*b*) There may be a simple splitting of polycyclic (asphaltic) hydrocarbons. (*c*) There may be a dehydrogenation of naphthene hydrocarbons.

New View on the Grading of Sand for Concrete and Cement Mortar. R. H. McNEILLY. (*Engineering Record*, vol. 72, No. 22, November 27, 1915.)—Sand for concrete and cement mortar, according to the accepted theory, should have its particles uniformly graded. Proceeding on theoretical grounds, confirmed by tests with laboratory mixtures, Professor McNeilly concluded that there should be a "jump" in the grading; that the best sizing will include particles caught between the No. 4 and the No. 10 sieves and the fines passing through a No. 40 sieve. A new material is accordingly proposed for Portland cement concrete consisting of four ingredients instead of the customary three. These four are (*a*) coarse aggregate, (*b*) coarse particles of the fine aggregate, (*c*) very fine particles of the fine aggregate, which are mixed independently with the cement, and (*d*) cement.

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THE RÔLE OF CHEMISTRY IN THE WAR.*

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THE human race is living at the bottom of an ocean of atmosphere some six to seven miles deep. Although it is not always realized by the unscientific mind, this aërial sea has weight and exerts a pressure upon all bodies of approximately fifteen pounds to the square inch. Roughly speaking, and disregarding a small amount of rare gases and impurities, the air consists of about one-fifth oxygen and four-fifths of the inert gas nitrogen.

Every intelligent person knows that oxygen is the breath of life, and that nitrogen serves the purpose of just sufficiently diluting the oxygen so that the combustion of waste carbon conveyed by the blood to the body tissues goes on at the steady rate which conforms to the life processes of all animals. With this general knowledge in regard to the element nitrogen, the ordinary, well-informed, non-technical man rests content.

Educated people are, of course, aware that fixed nitrogen in combination with carbon, hydrogen, and some few other minor elements is built up by vegetable life and, in turn, assimilated into the bodies of animals, thus supplying our food of almost every variety. It is also fairly well understood that in the processes of digestion the complex nitrogenous bodies built up by plant life

* Communicated by the Author.

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are broken down to simpler forms, in part supplying animal life energy and in part being voided by the animal, the manurial nitrogen products going back to the soil, thus completing what is known as the nitrogen cycle, caught in the wheel of which all material life, including the much-vaunted culture and progress of modern civilization, hangs suspended.

One thing that is not very generally apprehended by educated people, however, is that without fixed nitrogen in great abundance mankind could not wage war upon one another under modern conditions. Ever since gunpowder replaced the bow and arrow, fixed nitrogen has been used by man to hurl destructive missiles at his adversaries. In fact, it should be stated that no explosive substance has ever been used in peace or war which did not depend for its activity on the extraordinary properties of the element nitrogen, which, as the major constituent of the air we breathe, could almost be said to content itself with the inert and pacific rôle of toning down the activities of its restless neighbor, oxygen.

I.

THE RÔLE OF NITROGEN.

It becomes evident, from what has been said, that there must be some vital and important difference in character or quality between what may be termed *fixed* and *unfixed nitrogen*. In other words, it should be understood that all life and phenomenal existence, on this planet at least, depend upon the simple fact that the element nitrogen is able to assume two rôles, in one of which it is unfixed, inert, sluggish, and slow to enter into combination with other elements, and in the other of which it is active, reactive, restless, ever ready to break down into new combinations, absorbing and giving out enormous energy as the restless changes take place. Whether the changes take place in a measured and orderly fashion, as in plant-cell growth and animal digestion, or with the most sudden and terrible violence, as in the case of high explosives, the energies either absorbed or released are equally potent and measurable. The celebrated chemist Berzelius once said of the element nitrogen as it occurs in the air, it is difficult to recognize by any conspicuous property, but can only be recognized by means of properties which it does not possess.

Before pursuing our subject further, it will be necessary to make quite clear what is meant by inert, unfixed nitrogen and

active or fixed nitrogen. This explanation must be made in such a way that all apparent contradictions will immediately disappear. Gaseous nitrogen as it exists in the atmosphere has been proved by scientific methods to consist of a molecule made up of two atoms bound together by the equivalent of three bonds of affinity. What is meant is made clearer if we write a sort of alphabetical expression of the inert nitrogen molecule, as follows:

$$N \equiv N$$

It should not be supposed that the three bonds are actually arms or linkages holding the atoms together; they simply represent actually existent atomic forces, so that we may say that the element nitrogen is trivalent. In the same way we know that the element hydrogen is univalent, and we may express this by writing H – H, for the molecule of hydrogen is also known to be diatomic.

Now, suppose that by some means it is desired to combine or fix nitrogen to hydrogen; it is at once apparent that we should have to expend energy to tear apart the molecular bonds before we can fix the two elements together. In other words, the $N \equiv N$ would have to pass through the condition $N\equiv$ and $\equiv N$. Similarly, the H – H would have to split up into H – and – H. Subsequently, the two elements might combine to form ammonia,

$$N \begin{array}{l} -H \\ -H. \\ -H \end{array}$$

For the purpose of this paper it is not necessary to go deeper into the combining valences of the different elements which it will be necessary to discuss. Only the simplest combination of nitrogen and hydrogen, viz., ammonia, has been mentioned in order to show the difference between fixed nitrogen and the inert or unfixed state of this gas as it exists in the air, with all its chemical affinities self-satisfied; in short, in the condition $N \equiv N$. If, however, this union is torn apart, $N\equiv$ is in an actively unsatisfied state and is prepared to fix itself into myriads of combinations with other elements. In other words, the molecule of nitrogen is quiet and well behaved, whereas the free atom of nitrogen is dynamically and even, in some combinations, very terribly reactive. It is this underlying chemical fact that has enabled men

to slaughter and destroy each other on the gigantic scale now being demonstrated.

Those who have followed this explanation will readily see that it is not possible to maintain nitrogen in the condition of free unsatisfied atoms ($N\equiv$), for the simple reason that these atoms would return to the stable, quiescent molecule ($N\equiv N$), possibly with explosive energy. In order to take advantage of the reactive condition, it is necessary to lightly fix the nitrogen atom to some other atoms or groups of atoms in such a manner or in such a combination that the nitrogen at a blow can be suddenly released. Let us take the simplest example of what is meant. By an experiment so simple that the merest tyro in chemistry can perform it, ammonia can be made to react with the univalent element iodine to form the compound known as nitrogen iodide, in which iodine is made to replace the hydrogen, so that

$$N\begin{array}{l}-H\\-H\\-H\end{array} \text{ becomes } N\begin{array}{l}-I\\-I\\-I\end{array}.$$

Now, this nitrogen iodide is a brown powder which, when carefully dried, will remain innocently enough, resting quietly unchanged. If, however, we even so much as tickle this brown substance with a feather, or even if a door in the building in which it lies is rudely slammed, a terrible detonating explosion will occur, and the air will be filled with the stifling, violet-colored fumes of iodine. A quantity of this powder which could be heaped on the surface of a small silver coin would be sufficient to wreck everything in its neighborhood.

Whence this extraordinary energy? The thermodynamics of this and similar reactions are too complicated and mathematical to discuss here, but it is easy to see that the atomic forces at work in the sudden liberation of free nitrogen and iodine atoms, and their instantaneous rearrangement into inert molecules, involve enormous energy effects. Of course, nitrogen iodide is too treacherous a substance to be used as a high explosive, for in the dry condition the merest jar would cause it to detonate. It is obvious, therefore, that it has been the task of the chemist to find ways of locking nitrogen to other elements or groups of elements, with the result that it will be fixed tightly enough so that premature explosion will be avoided, but not so tightly but that it can be exploded by small quantities of more reactive nitrogen compounds made up in the form of percussion caps or detonators.

All modern high explosives are just such chemical combinations of nitrogen as this, and we have, among others, nitroglycerin (dynamite), nitrocellulose (gun-cotton), trinitro-phenol (picric acid), nitrogelatine, trinitro-benzene, trinitro-toluene, etc. Masked under such trade names as Lyddite, Melinite, Turpenite, Cordite, etc., these nitrogen compounds are products of modern chemistry known and used by the armies and navies of the world.

In a later paragraph we shall have occasion to return to the constitutions of these more complicated nitro substitution products. For the present, it will be necessary to inquire into the source and supply of the combined or fixed nitrogen on which modern warfare depends.

On the western coast of South America, in Chile and Peru, there occur vast natural deposits of nitrate of sodium, commonly known as Chile saltpetre. These deposits, with certain exceptions which will be noted later, constitute the world's supply of fixed or combined nitrogen, and in times of peace set the price for all combined nitrogen from whatsoever source derived. In sodium nitrate the nitrogen is linked to oxygen. Treated with sulphuric acid, which is cheap and abundant, sodium nitrate yields nitric acid. Various organic substances treated under certain conditions with nitric acid yield nitro substitution bodies which are used as dyes, while other of these bodies are the high explosives referred to above. But sodium nitrate, for reasons that will now be apparent to the reader, is necessary as a fertilizer to keep up the fertility of the soil and thus make it possible for mankind to work out his destiny through the nitrogen cycle to which he is linked. It is indeed a curious thought that these natural deposits in a more or less remote corner of the world should exercise so great an influence on man and in so diverse a manner: on his life in the growth of the food he eats, and on his death in the production of destructive explosive agents, capable of killing thousands at a single blow.

In spite of the vastness of the Chilean nitrate beds, thoughtful scientific men have for many years given warning of the danger of their exhaustion. In 1898, Sir William Crookes, in his presidential address before the British Association for the Advancement of Science, dwelt in the most earnest manner upon the importance of this problem, and urged upon the attention of chem-

ists and physicists the necessity for developing methods for fixing the inexhaustible supply of nitrogen in the air.

The present annual output of the Chilean fields amounts to about 2,500,000 tons. A recent scientific article [1] on this subject states:

While there are a few scattered natural deposits other than those in Chile, there is none which has at the present time a chance of competing, most of them being of limited extent and situated in inaccessible regions. In Chile the deposits are easily worked, and even after years of careless mining, with no effort to effect economies, the present cost of producing nitrate is not excessive, varying from $10 to $20 per ton and selling in Liverpool for about $45 per ton. This leaves a profit of from $5 to $10 a ton on the operation, after paying the Government of Chile an export tax of about $12.25 per ton. In the past thirty years this export tax has netted the Chilean Government about $500,000,000. Of the total production of Chile, the United States imports about 600,000 to 700,000 tons per annum, the balance being practically all shipped to European countries. Chile saltpetre has sold for as high as $60 a ton, but since 1909, when the agreement among the producers expired, the price has approximated $45 per ton f. o. b. Liverpool, making a price of from $35 to $40 per ton f. o. b. Chile.

According to the same authority quoted above, 50 per cent. of all the Chile saltpetre imported into the United States is used in the manufacture of explosives, while an additional 25 per cent. is utilized in the arts requiring nitric acid. The balance, or 25 per cent., presumably finds its way to the soil as an intensive nitrogen fertilizer.

Let us now see what statistics will show in regard to the proportion of the two and one-half million tons of nitrate produced in Chile which is yearly imported into this country. The foreign commerce reports of the United States Department of Commerce have made the following figures available:

Nitrate of Soda Imported into the United States for the Twelve Months Ending June——

1913		1914		1915	
Tons	Value	Tons	Value	Tons	Value
589.136	$20,718,968	564,049	$17,950,786	577.122	16,355,701

These figures are interesting and can be interpreted in their relation to world conditions during the years included. They at

[1] "Fixation of Atmospheric Nitrogen," Leland L. Summers, *Trans. Amer. Electrochem. Soc.*, xxvii, 340–341, 1915.

once suggest a number of questions which it will be interesting to note down.

1. Since the United States normally has taken about one-fifth of the world supply of nitrate, and since 75 per cent. of this goes for the manufacture of explosives and nitric acid, what would happen to the United States if it were attacked by a strong naval power which would be able to blockade the western coast of South America and the entrance to the Panama Canal?

2. What reserve supply of fixed nitrogen have we in the United States in case we were called upon to wage a defensive war, and does any one in authority in the United States show any indication of caring at all about this important matter? *

3. Since Germany and Austria have lost command of the sea, where are they getting the enormous supplies of fixed nitrogen necessary for their war against the world?

4. Assuming that England, France, Russia, Italy, and Japan are between them using 2,000,000 tons of Chilean nitrate for the manufacture of explosives, is the quantity adequate to the task they have undertaken?

The answers to these questions, though not treated *seriatim,* will be discussed in the following paragraphs.

In the great iron and steel industries of the world vast quantities of coal have to be partially burned to coke. In this process large quantities of valuable by-products are driven off and can be collected and used for many purposes, both in the peaceful arts and in war. To our everlasting shame be it said that we have for the most part, by the use of the open beehive-shaped coke ovens, allowed these valuable by-products to escape into the air and be lost. One, at least, of the good things that the present war has accomplished is in showing us the folly of such insane waste of valuable material. The substitution of the open type of coke oven by the enclosed by-product recovery oven is now at last going on apace. Our coking coals contain about one per cent. of fixed

* Since this article went to press, announcements have appeared in the daily press, stating that Brigadier-General William M. Crozier, Chief of Ordnance of the United States Army, in his annual report has urged that the nation take steps to be independent of the Chilean beds for the nitrates used in making gunpowder. In addition to this, it is reported that Mr. James B. Dukes announces that his company will turn out four tons daily at once of nitric acid made from nitrogen of the air. If these press reports are correct, answers to some of the questions considered in this paper are already in hand.

nitrogen, and this can all be saved and converted into ammonia or the sulphate of ammonia. It will be remembered that once we have our nitrogen fixed we can use it as fertilizer or convert it by chemical processes into useful products, including high explosives.

Among the coke recovery products we get coal tar, which, in turn, yields such valuable intermediates as benzene, toluene, and aniline, used in the manufacture of an infinite number of dyes, medicines, and explosives. The annual world's production of sulphate of ammonia from gas works and by-product coke ovens now amounts to about 1,250,000 tons, and the Liverpool price approximates that of sodium nitrate, varying from $45 to $60 per ton.

It will be seen, from the above figures, that, while by-product recovery from coke making offers an opportunity to eke out the needed supply of fixed nitrogen, taken by itself this source is insufficient to fill the demand in time of peace, and in time of war and embargo it would be quite inadequate, especially in the United States, where we are comparatively young in the application not only of by-product recovery but also in the chemical processes required to oxidize ammonia to the condition of nitric acid necessary for the manufacture of explosives.

Within the last fifteen years, or since Sir William Crookes sounded his note of warning to the world, chemists have paid especial attention to the problem of the fixation of the inexhaustible supply of nitrogen in the air. There are three lines of attacking this problem, along which substantial success has been attained: *First,* the nitrogen can be made to combine directly with the oxygen of the air to form nitric acid; *second,* the nitrogen can be induced to combine with carbon to form cyanamide (C_2N_2), which can be used directly as a fertilizer or by subsequent treatment changed into ammonia, and hence to nitric acid; and, *third,* nitrogen can be directly linked to waste or by-product hydrogen from other chemical industries to form ammonia. There are also other indirect processes which have been proposed for fixing atmospheric nitrogen, but these need not be discussed here.

It is apparent, from what has been said in an earlier part of this article, that enormous energy is called for in breaking up the linkage $N \equiv N$ and fixing the nitrogen atoms to other atoms, such as oxygen, carbon, and hydrogen. It will not be surpris-

ing, therefore, to learn that the success of such industries must hang, for the most part, on the successful harnessing of great water powers to this end. We have our Niagara and many other great potential water powers in North America; let us inquire, therefore, what we have done in this country toward the solution of this problem with which the future of the human race is so inevitably bound up.

Perhaps it might be permitted to begin this portion of the discussion with the statement that we in the United States have accomplished practically nothing at all along this line. It is a curious fact, often made a subject of comment, that in America have been made nearly all the inventions on which modern warfare depends, all of which, for lack of public interest and financial backing, have passed for their development to foreign countries. This is true of the aëroplane, the dirigible, the submarine, and it is equally true of the nitrogen-fixation processes. In 1902 two American pioneers, Lovejoy and Bradley, established at Niagara Falls their first industrial apparatus for fixing the nitrogen to the oxygen of the air by means of the electric arc and thereby directly producing nitric acid. These pioneers were on the right track, but nobody cared, least of all our government, and so the infant industry died of inanition. I shall now dare to say that it is the development of this pioneer work in the hands of foreign scientists and engineers that made it possible for Germany to challenge a world at arms. Dr. L. H. Baekeland, in the Chandler lecture for 1914, has so excellently summed up the status of nitrogen fixation that no one could improve upon his brief capitulation, nor can Dr. Baekeland's summary be too often printed for the instruction of our countrymen. This eminent authority says:

The development of some problems of industrial chemistry has enlisted the brilliant collaboration of men of so many different nationalities that the final success could not, with any measure of justice, be ascribed exclusively to one single race or nation; this is best illustrated by the invention of the different methods for the fixation of nitrogen from the air.

This extraordinary achievement, although scarcely a few years old, seems already an ordinary link in the chain of common, current events of our busy life; and yet the facts connected with this recent conquest reveal a modern tale of great deeds of the race—an Epos of Applied Science.

Its story began the day when chemistry taught us how indispensable are the nitrogenous substances for the growth of all living beings.

Generally speaking, the most expensive foodstuffs are precisely those which contain most nitrogen; for the simple reason that there is, and always has been, at some time or another, a shortage of nitrogenous foods in the world. Agriculture furnishes us these proteid- or nitrogen-containing bodies, whether we eat them directly as vegetable products, or indirectly as animals which have assimilated the proteids from plants. It so happens, however, that by our ill-balanced methods of agriculture we take nitrogen from the soil much faster than it is supplied to the soil through natural agencies. We have tried to remedy this discrepancy by enriching the soil with manure or other fertilizers, but this has been found totally insufficient, especially with our methods of intensive culture—our fields want more nitrogen. So agriculture has been looking anxiously around to find new sources of nitrogen fertilizer. For a short time an excellent supply was found in the guano deposit of Peru; but this material was used up so eagerly that the supply lasted only a very few years. In the meantime the ammonium salts recovered from the by-products of the gas-works have come into steady use as nitrogen fertilizer. But, here again, the supply is entirely insufficient, and during the later period our main reliance has been placed on the natural beds of sodium nitrate, which are found in the desert regions of Chile. This has been, of late, our principal source of nitrogen for agriculture, as well as for the many industries which require saltpetre or nitric acid.

In 1898, Sir William Crookes, in his memorable presidential address before the British Association for the Advancement of Science, called our attention to the threatening fact that, at the increasing rate of consumption, the nitrate beds of Chile would be exhausted before the middle of this century. Here was a warning—an alarm—raised to the human race by one of the deepest scientific thinkers of our generation. It meant no more nor less than that before long our race would be confronted with nitrogen starvation. In a given country, all other conditions being equal, the abundance or the lack of nitrogen available for nutrition is a paramount factor in the degree of general welfare or of physical decadence. The less nitrogen there is available as foodstuffs, the nearer the population is to starvation. The great famines in such nitrogen-deficient countries as India and China and Russia are sad examples of nitrogen starvation.

And yet nitrogen, as such, is so abundant in Nature that it constitutes four-fifths of the air we breathe. Every square mile of our atmosphere contains nitrogen enough to satisfy our total present consumption for over half a century. However, this nitrogen is unavailable so long as we do not find means to make it enter into some suitable chemical combination. Moreover, nitrogen was generally considered inactive and inert, because it does not enter readily into chemical combination.

William Crookes's disquieting message of rapidly-approaching nitrogen starvation did not cause much worry to politicians—they seldom look so far ahead into the future. But to the men of science it rang like a reproach to the human race. Here, then, we were in possession of an inexhaustible store of nitrogen in the air, and yet, unless we found some practical means for tying some of it into a suitable chemical combination, we would soon be in a posi-

tion similar to that of a shipwrecked sailor, drifting around on an immense ocean of brine, and yet slowly dying for lack of drinking water.

As a guiding beacon there was, however, that simple experiment, carried out in a little glass tube as far back as 1785 by both Cavendish and Priestley, which showed that if electric sparks were passed through air the oxygen thereof was able to burn some of the nitrogen and to engender nitrous vapors.

This seemingly unimportant laboratory curiosity, so long dormant in the text-books, was made a starting-point by Charles S. Bradley and D. R. Lovejoy, in Niagara Falls, for creating the first industrial apparatus for converting the nitrogen of the air into nitric acid by means of the electric arc.

As early as 1902 they published their results, as well as the details of their apparatus. Although they operated only one full-sized unit, they demonstrated conclusively that nitric acid could thus be produced from the air in unlimited quantities. We shall examine later the reasons why this pioneer enterprise proved a commercial failure; but to these two American inventors belongs, undoubtedly, the credit of having furnished the first answer to the distress call of Sir William Crookes.

In the meantime many other investigators were at work at the same problem, and soon from Norway's abundant waterfalls came the news that Birkeland and Eyde had solved successfully, and on a commercial scale, the same problem by a differently-constructed apparatus. The Germans, too, were working on the same subject, and we heard that Schoenherr, also Pauling, had evolved still other methods, all, however, based on the Cavendish-Priestley principle of oxidation of nitrogen. In Norway alone the artificial saltpetre factories use now, day and night, over 200,000 electrical horse-power, which will soon be doubled; while a further addition is contemplated which will bring the volume of electric current consumed to about 500,000 horsepower. The capital invested at present in these works amounts to $27,000,000.

Frank and Caro, in Germany, succeeded in creating another profitable industrial process, whereby nitrogen could be fixed by carbide of calcium, which converts it into calcium cyanamide, an excellent fertilizer by itself. By the action of steam on a cyanamide, ammonia is produced, or it can be made the starting-point of the manufacture of cyanides, so profusely used for the treatment of gold and silver ores.

Although the synthetic nitrates have found a field of their own, their utilization for fertilizers is smaller than that of the cyanamide; and the latter industry represents to-day an investment of about $30,000,000, with three factories in Germany, two in Norway, two in Sweden, one in France, one in Switzerland, two in Italy, one in Austria, one in Japan, one in Canada, but not any in the United States. The total output of cyanamide is valued at $15,000,000 yearly and employs 200,000 horse-power, and preparations are made at almost every existing plant for further extensions. An English company is contemplating the application of 1,000,000 horse-power to the production of cyanamide and its derivatives, 600,000 of which have been secured in Norway and 400,000 in Iceland.

But still other processes are being developed, based on the fact that certain metals or metalloids can absorb nitrogen, and can thus be converted

into nitrides; the latter can either be used directly as fertilizers or they can be made to produce ammonia under suitable treatment.

The most important of these nitride processes seems to be that of Serpek, who, in his experimental factory at Niedermorschweiler, succeeded in obtaining aluminum nitride in almost theoretical quantities, with the use of an amount of electrical energy eight times less than that needed for the Birkeland-Eyde process and one-half less than for the cyanamide process, the results being calculated for equal weights of "fixed" nitrogen.

A French company has taken up the commercial application of this process which can furnish, besides ammonia, pure alumina for the manufacture of aluminum metal.

An exceptionally ingenious process for the direct synthesis of ammonia, by the direct union of hydrogen with nitrogen, has been developed by Haber in conjunction with the chemists and engineers of the Badische Aniline and Soda Fabrik.

The process has the advantage that it is not, like the other nitrogen-fixation processes, paramountly dependent upon cheap power; for this reason, if for no other, it seems to be destined to a more ready application. The fact that the group of the three German chemical companies which control the process have sold out their former holdings in the Norwegian enterprises to a Norwegian-French group, and are now devoting their energies to the commercial installation of the Haber process, has considerable significance as to expectations for the future.

The question naturally arises: Will there be an overproduction and will these different rival processes not kill each other in slaughtering prices beyond remunerative production?

As to overproduction, we should bear in mind that nitrogen fertilizers are already used at the rate of about $200,000,000 worth a year, and that any decrease in price, and, more particularly better education in farming, will probably lead to an enormously increased consumption. It is worth mentioning here that, in 1825, the first shipload of Chile saltpetre which was sent to Europe could find no buyer, and was finally thrown into the sea as useless material.

Then, again, processes for nitric acid and processes for ammonia, instead of interfering, are supplementary to each other, because the world needs ammonia and ammonium, as well as nitric acid or nitrates.

It should be pointed out, also, that, ultimately, the production of ammonium nitrate may prove the most desirable method so as to minimize freight; for this salt contains much more nitrogen to the ton than is the case with the more bulky calcium-salt under which form synthetic nitrates are now put into the market.

Before leaving this subject, let us examine why Bradley and Lovejoy's efforts came to a standstill where others succeeded.

First of all, the cost of power at Niagara Falls is three to five times higher than in Norway, and, although at the time this was not strictly prohibitive for the manufacture of nitric acid, it was entirely beyond hope for the production of fertilizers. The relatively high cost of power in our country is the reason why the cyanamide enterprise had to locate on the

Canadian side of Niagara Falls, and why, up till now, outside of an experimental plant in the South (a 4000 horse-power installation in North Carolina, using the Pauling process), the whole United States has not a single synthetic-nitrogen fertilizer works.

The yields of the Bradley-Lovejoy apparatus were rather good. They succeeded in converting as much as 2½ per cent. of the air, which is somewhat better than their successors are able to accomplish.

But their units, 12 kilowatts, were very much smaller than the 1000 to 3000 kilowatts now used in Norway; they were also more delicate to handle, all of which made installation and operation considerably more expensive.

However, this was the natural phase through which any pioneer industrial development has to go, and it is more than probable that, in the natural order of events, these imperfections would have been eliminated.

But the killing stroke came when financial support was suddenly withdrawn.

In the successful solution of similar industrial problems the originators in Europe were not only backed by scientifically well-advised bankers, but they were helped to the rapid solution of all the side problems by a group of specially-selected scientific collaborators, as well as by all the resourcefulness of well-established chemical enterprises.

That such conditions are possible in the United States has been demonstrated by the splendid teamwork which led to the development of the modern tungsten lamp in the research laboratories of the General Electric Company, and to the development of the Tesla polyphase motor by the group of engineers of the Westinghouse Company.

True, there are endless subjects of research and development which can be brought to success by efforts of single independent inventors, but there are some problems of applied science which are so vast, so much surrounded with ramifying difficulties, that no one man, nor two men, however exceptional, can furnish either the brains or the money necessary for leading to success within a reasonable time. For such special problems the rapid cooperation of numerous experts and the financial resources of large establishments are indispensable.

So much for the rôle of chemistry in the war in so far as it is affected by the nitrogen-fixation problem. Those who have read thus far will be able to formulate their own answers to the questions set down in an earlier paragraph and will understand how Germany, although cut off from the South America nitrate fields, has been able to assemble and use more high explosives in a shorter time than any one would have believed possible previous to the year of grace (*sic*) 1914.

If we assume that the nations at war have provided themselves with adequate supplies of fixed nitrogen in the condition of nitric acid, let us now return to a more detailed discussion of the materials and methods which modern chemistry uses for the

production of high explosives, without an abundant supply of which modern warfare must immediately come to an end. We have seen in what manner the nations are in fact fighting with fixed nitrogen. Indeed, it may be said that out of the atmosphere comes the power of making war, for there are geological reasons for believing that the nitrogen of the Chile nitrate beds was originally fixed by natural process from atmospheric nitrogen. We must now consider something of the chemistry of the element carbon and the wonderful rôle which it also plays in war.

II.

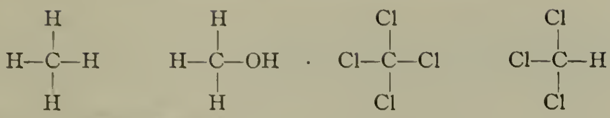
THE RÔLE OF CARBON.

The element carbon, unlike nitrogen, does not appear in Nature in the gaseous form. It is familiar to every one in an impure form as coal, as charcoal and graphite, and in its pure crystallized form as the diamond. Considered as an atom in its chemical sense, it is highly reactive and ever ready to combine with other atoms and groups of atoms to form the endless variety of organic forms which make up the visible universe. The most characteristic attribute of the carbon atom is its power and tendency to link up with other carbon atoms, thus permitting an infinite variety of molecular architecture. It will be necessary to follow this statement a little further, on account of its bearing on the rôle of chemistry in the war.

We have seen that the free atom of nitrogen is called trivalent and is written $\mathrm{N}\equiv$. Similarly, the free atom of carbon is known to be quadrivalent and might be written $\mathrm{C}\overline{\equiv}$. As a matter of fact, however, the quadrivalence of the carbon atom is expressed in the following form:

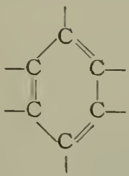
$$\begin{array}{c} | \\ -\mathrm{C}- \\ | \end{array}$$

Really the carbon atom with its four bonds is thought of spacially as being at the centre of a pyramid or tetrahedron. For our present purpose, however, we need not confuse ourselves with this conception, but think of it as written above. The point to be understood is that the free affinities of the carbon atom are easily saturated with other atoms or groups of atoms, as, for instance, in the following compounds:

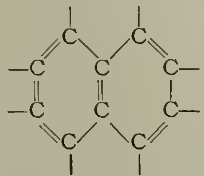


Marsh gas (methane) Methyl alcohol Carbon tetrachloride Chloroform

But the most interesting characteristic is the ability of carbon to link up as in $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$ and $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$ and so on until we reach a string or nucleus of six atoms, when in many cases the string acts as though it were unwieldy and, like a snake with its tail in its mouth, links up into form of a ring known as the benzene ring, and written:



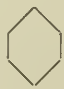
or further into double or even triple rings:



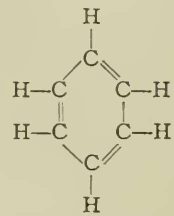
It may appear to the layman that we are involving ourselves pretty deeply in advanced chemistry, but we must be patient, because we are getting close to the secret of modern warfare as it is controlled by high explosives. We are also getting close to the secrets of the dye industry and modern medicinals, which subjects have been much discussed in this country since the outbreak of the war.

Benzene has already been referred to in an earlier paragraph as a by-product of the coke and gas industry. It is a limpid liquid substance which closely resembles gasoline in odor and properties. If cheap enough, it could be used in automobile engines, but its price before the war in this country was about thirty cents a gallon, which was prohibitive of its use for this purpose. It is an important raw material for the manufacture of high explosives, dyes, synthetic medicines, phonographic records, etc. Benzene has the chemical formula C_6H_6, and is to be considered as a ring of six carbon atoms attached as shown above, with one hydrogen atom fixed to each carbon. For the sake of brevity and simplicity, chemists no longer take the trouble to write in the carbon or hydrogen atoms into their ring formulæ, these being assumed, only the significant substituting atoms being placed and written

in. Thus, for instance, the benzene or, as the Germans call it, the benzol ring is expressed by writing:

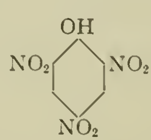


instead of the more cumbersome



Now, suppose by treating benzene with certain chemicals we replace one of the hydrogens by the group of atoms OH, we get

This body is carbolic acid, known to chemists as phenol. It was this substance that we have read in the newspapers Thomas A. Edison needed for making phonograph records after the German supplies ceased, and which he was able to make as soon as the recovered benzol began to be available from the American gas and coke plants. Now, if we start again with phenol and treat it with nitric acid in a special manner, we make trinitro-phenol, or picric acid, an intensely yellow substance which is used as a dye base and is also one of the most deadly of the high explosives. We write the formula of picric acid

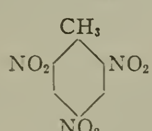


and designate it as a 2, 4, 6 substitution product, for the group or radical NO_2 must fix to just the right points in the carbon ring, or we should not get picric acid, but something else. Perhaps we have now succeeded in getting a glimpse into the wonderful molecular architecture that has been patiently worked out by chemists for the use of man in the arts of peace and war. Untold numbers of tons of picric-acid mixtures under the names of Melinite and Turpenite are being shot off on the European battlefields.

Looking at the graphic representation of the picric-acid molecule written above, it requires but a slight effort of the imagination to picture what takes place when this molecule is suddenly shattered into its elements. Large quantities of hot nitrogen, hydrogen and oxygen atoms are instantly set free, seeking to expand and satisfy their various affinities. The chemical forces of disruption and rearrangement are titanic and, when directed to that end, scatter death and destruction round about.

Picric acid, when dry, melts down quietly at a little above the water-boiling temperature, with little danger of explosion unless it is detonated by something else. It is usually melted down with rosin or some other body which is used to dilute it. It is these other bodies which are partly responsible for the dense clouds of black smoke formed when shells loaded with picric-acid mixtures explode, and which on the European battlefields have earned for them the name of "Jack Johnsons."

Toluene * is a near relative of benzene; it is a liquid slightly less volatile than the latter substance, and is also a by-product of the coke and gas industry. From it we can obtain trinitro-toluene—



This product is also used as a modern high explosive, under the abbreviated name of T. N. T.

The German chemical industries are said to have accumulated vast stores of these and similar by-product nitro-substitution products from their great dye industries. The well-known blue dye, indigo, which used to be extracted from a plant grown in India, is now made synthetically in Germany, and the by-products from the synthesis furnish some of the raw material for the nitro bodies used in explosives. It is said to have taken the patient German chemists over twenty years to work out the synthesis of indigo, but when this was finally accomplished the natural indigo soon disappeared from the markets of the world.

Glycerine is a by-product from the manufacture of soap. By nitration we get nitroglycerin, which, when soaked up in an inert,

* It is interesting to note that the price of benzene has risen from 30 cents to 90 cents a gallon since the war began. Toluene has risen in the same time from 40 cents to $5.00 per gallon.

earthy powder, we call dynamite. Cotton consists mainly of cellulose. When cotton is nitrated, nitro-cellulose or gun-cotton is obtained. When compressed into blocks or other forms, this gun-cotton is a detonating explosive of terribly high power, and is frequently used for loading torpedoes and mines. When made in a different way, however, nitro-cellulose does not detonate but burns rapidly, giving off large quantities of hot expanding gases. When in this form nitro-cellulose is known as "smokeless powder." It is generally not used as a powder, however, but in the form of sticks (cordite) or short cylinders through which holes are bored to facilitate rapid combustion. If cotton can not be obtained, as is probably now the case in Germany, wood-pulp cellulose may be substituted. Gelatine made from slaughter-house refuse or dead horses can in like manner be used in the production of nitro-gelatine. The chemistry of these substances is more complicated than in the cases of nitro-benzene and toluene, so that we need not attempt to go more deeply into the subject in this place. Enough has been said to show the rôle of the chemistry of carbon and nitrogen as this applies to modern warfare.

III.

THE RÔLE OF HYDROGEN.

Hydrogen is the lightest gas known, being about seven times lighter than air, bulk for bulk. The manufacture of caustic alkali on an enormous scale is necessary to every civilized nation for the manufacture of paper, soap, and many other necessities of life. This alkali is in part manufactured by an electric water-power process which yields hydrogen as one of its by-products. At present about 30,000 electrical horse-power are employed in this branch of industry in the United States. In Germany all waste hydrogen is conserved for filling the balloons of Zeppelins and presumably for making synthetic ammonia by the Haber process, as well as for other industrial purposes. In this country practically all the hydrogen is allowed to escape into the air, to seek the outermost reaches of the atmospheric sea. It is probable, however, that the day is not far distant when we, too, will meet the necessity of conserving our hydrogen as well as our other useful industrial wastes.

The story of the development of the Haber process for fix-

ing the nitrogen of the air to by-product hydrogen reads like a fairy tale of science wedded to patience. About twenty-five years ago American students of chemistry at a certain German university were surprised to find their professors carrying on patient researches on methods for oxidizing ammonia to nitric acid. Since in those days nitric acid cost less than ammonia, and as no methods for fixing the nitrogen of the air had even been proposed, so much patient work seemed at best to be premature. The fact is, however, that it was to come about that the great European war was to await the word "Go!" not alone from the statesmen and militarists but also from the distinguished chemist-privy councillors (*Geheimraths*) of the German Empire. At the meeting of the Eighth International Congress of Applied Chemistry held in New York in September, 1912, the German Professor H. A. Bernthsen, in the course of his address,[2] said:

I propose, however, to-day to deal, from my own direct experience, with the development of the *problem for the synthetical manufacture of ammonia from its elements.* A few years ago the solution of this problem appeared to be absolutely impossible. It has recently been the object of very painstaking investigations by Professor Haber and the chemists of the Badische Anilin- and Soda-Fabrik, and numerous patents have been taken out with reference to the manufacture. Apart from what is already published in this way, however, we have refrained from any other announcements until we were in a position to report something final with reference to the solution of the technical question.

This moment has now arrived, and I am in the agreeable position of being able to inform you that the said problem has now been solved fully on a manufacturing scale, and that the walls of our first factory for synthetic ammonia are already rising above the ground at Appau, near Ludwigshafen-on-Rhine.

So much for the accomplishment of Germany's independence of Chile saltpetre up to 1912. The fact that the contact process for changing synthetic ammonia to nitric acid had already been worked out tells us something of the vision that was in the minds of German scientists at least a quarter of a century ago.

But let us hear further from Professor Bernthsen on some of the difficulties that had to be surmounted before this method of nitrogen fixation was an accomplished fact. He goes on to say:[3]

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[2] "Synthetic Ammonia," H. A. Bernthsen, *Trans. Eighth Internat. Cong. Applied Chem.*, vol. xxviii, pp. 185 and 186.

[3] *Ibid.*, pp. 193–194, 199–200.

The problems to be solved were quite new and strange and demanded the mastery of very unusual difficulties. Although working with compressed gases under pressure at very low temperatures was already known in the industry, the problem here was the totally different one of constructing apparatus which should be large enough and at the same time able to withstand the high pressure with temperatures not far from a red heat. How well founded were the doubts as to the possibility of a solution of this task can be gathered from the instance of the wrought-iron autoclaves commonly used in the color industry. Here, in spite of a very low range of temperature of at most 280° C., only pressures of from 50 to 100 atmospheres at the utmost come into consideration. But above 400° C. iron loses its solidity to a very extraordinary degree.

There is, further, the circumstance that the metals which come into consideration for the construction of the apparatus, and especially iron, are chemically attacked above certain temperatures by the gas mixture under pressure. Although the formation of iron nitride from iron and ammonia, which could have been expected according to the work of Fremy and others, can be avoided, yet it is found, for example, that steel containing carbon loses its carbon at the temperatures in question, owing to the action of the hydrogen, so that its capability of withstanding pressure is reduced to a minimum. It was further found, when using iron itself, that it is completely changed in its qualities, chiefly by taking up hydrogen. Again, at such high temperatures iron is pervious to quite a remarkable degree to hydrogen under high pressures. The question of materials for the apparatus, therefore, raised at once considerable difficulties, but at length these were more than overcome by suitable construction, details of which, I am sure, you will not expect from me to-day. The danger of serious explosions or of great, sudden flames of hydrogen, if the apparatus happens to become defective, can be guarded against by setting it up in bomb-proof chambers.

Great care must naturally be taken that oxygen or air does not get into the apparatus or the piping, for at the high pressure obtaining the explosion range is reached with merely a slight percentage of oxygen. Special devices are used to watch over this content of oxygen, and immediately a definite percentage is touched the alarm is automatically raised. Besides this, the proper constitution of the gas mixture in circulation is controlled by analysis from time to time.

The *ammonia* can be *removed* either by being drawn directly from the apparatus in liquid form, or an absorption agent can be suitably introduced into the apparatus. The simplest absorbent, water, has been found to be suited for this purpose; under the pressure used a concentrated solution of ammonia is secured. Any ammonia that may remain in the gas after the bulk has been removed by one or other of these methods can be further removed by special chemical means, if it is not preferred simply to leave it in the circulating gases.

. . . .

The question has not yet been touched upon in the foregoing, how the elements nitrogen and hydrogen which are requisite for the new ammonia process can best be produced on a technical scale. Theoretically, the task

would be unusually simple. If you remember that the terrestrial atmosphere, acording to the studies of A. Wagener and others, consists of practically pure hydrogen at a height of about 120 kilometres—indeed, at a height of about 70 kilometres consists of almost exactly one volume of nitrogen and three volumes of hydrogen, besides a trace (about one-half per cent.) of oxygen—you will understand that all the conditions were given for an ammonia factory according to Jules Verne; for it would then merely be necessary to suck down the gases from the higher strata of the atmosphere by a sufficiently long pipe line.

For us, poor mortals, matters are not so ideally simple, for, as the poet says,

"Hart im Raume stossen sich die Sachen."

Fortunately, however, there is no great difficulty in separating nitrogen from the air, either by physical means, according to Linde's process, or chemically, by removing the oxygen with glowing copper, burning hydrogen, or the like. And for the preparation of hydrogen in recent times a great deal of useful work has been done, too, owing to the extensive growth of its field of application. In certain works it is at disposal in large quantities as a by-product of the electrolysis of common salt. Besides this, it can be produced, for example, by passing steam over red-hot iron, or from water-gas, for instance, by separating its constituents, hydrogen and carbon monoxide, by cooling to a very low temperature. All the methods of preparation which come into consideration we have, of course, minutely examined; owing to the comparatively trifling differences in the cost of production various methods can be employed. At all events, both elements, nitrogen and hydrogen, are at the disposal of the new industry to any extent and sufficiently cheap.

As the production of these elements is not confined to the presence of cheap water-power, all those countries where the manufacture of calcium nitrate, owing to the want of such power, is not practicable, as, for instance, in Germany, are now in a position to profit by the new industry.

The above quoted matter makes interesting reading in the light of the history of the past three years. The synthesis of ammonia by the Haber process takes place by heating a mixture of hydrogen and nitrogen gas under enormous pressures in great alloy-steel bombs buried in bomb-proof cellars, and then rapidly withdrawing and cooling the synthetic ammonia $\left(\mathrm{N}\begin{matrix}-\mathrm{H}\\-\mathrm{H}\\-\mathrm{H}\end{matrix}\right)$ which is formed. But this is not all of the story.

Even when all these titanic arrangements have been made, the synthesis of ammonia does not take place unless a *catalyst* is present.

Is this fairy tale of science getting too deep for ordinary comprehension, and is it time, as Lewis Carroll's Walrus said,

to talk of other things, such as ships and shoes and sealing-wax and cabbages and kings?

But, as a matter of fact, could a world-war be declared or waged without every one of those four things or the things they stand for that the Walrus wanted to talk about?

And now we are also to learn that a world-war can not be waged without a catalyst! And what on earth is a catalyst?

Those who wish to follow this monster to its lair must be referred to the dictionaries and encyclopædias, but, after all, it is not so frightful as it sounds. In a few words, the meaning is this: A number of important and difficult chemical reactions will not take place, or only very slowly, unless some substance is present in such a manner that it can come into contact with the reacting bodies and thus act the rôle of a go-between promoter or introducer. Such a substance is not changed or necessarily wasted while the action is going on, but acts merely by contact.

Chemists have called this kind of action catalysis. Some one has said that the industrial development of a nation can be measured by the quantity of sulphuric acid that it produces, and it is interesting to note, in passing, that catalysts or contact agents have in modern times revolutionized the production of this most important substance. Catalysts consist usually of some metal or compound of a metal in finely-powdered or subdivided form. As they are not used up or wasted in doing their work, and only comparatively small quantities are needed, the rarest and most expensive metals, such, for instance, as platinum, can be used even in very large-scale operations. Haber found that such rare and unusual metals as molybdenum and tungsten made excellent catalysts for promoting the synthesis of ammonia. But here we have to refer to one of the most curious facts that has been developed by modern chemical research. It has been found that these catalysts can be poisoned by certain things very much in the same way as though they were living cells. That is to say, there are substances which hinder or prevent or kill the activity of these catalysts, although the contact mass does not suffer a noticeable chemical change, envelopment, or destruction. For instance, traces of arsenic mixed with the sulphur from which sulphuric acid is made will poison the platinum catalyzer, whereas it has been found that, on the contrary, the presence of arsenic will act fa-

vorably (or medicinally, as it were) when iron oxide is used as a catalyst.

We are now prepared to hear Professor Bernthsen [4] on this subject and to admire and marvel at the persistence and painstaking efforts made by modern science to overcome the obstacles with which Nature seems to surround her most profound secrets:

It has now been ascertained that some of the poisons in the synthesis of ammonia are of quite a different nature from those of the sulphuric acid process; they are, for instance, sulphur, selenium, tellurium, phosphorus, arsenic, boron, or the compounds of these elements, such as sulphuretted hydrogen, arsenic hydride, phosphorus hydride, as also many carbon compounds and certain metals of low melting-point which can readily be reduced by hydrogen from their compounds; for example, lead, bismuth, and tin, which do not act catalytically. Oxygen-sulphur compounds, such as SO_2, which acts directly and smoothly in the sulphuric-acid catalysis, are very poisonous. Extremely minute quantities of these bodies, which are almost always present even in the purest commercial products or in the so-called pure gases, suffice to render the catalysts absolutely inactive, or at least to diminish their action very seriously. Thus iron, for example, prepared from ordinary iron oxide with a content of one per thousand of sodium sulphate, is, as a rule, inactive. Iron containing one-tenth per cent. of sulphur is generally quite useless, and even with one-hundredth per cent. is of very little use, although in appearance and when examined with the ordinary physical and chemical methods no difference at all can be detected as compared with pure iron.

The recognition of these facts gave rise to two problems:

(*a*) The preparation of contact masses free from poison, or the removal of such poisons from them; and

(*b*) Freeing the gases to be acted on catalytically from all contact poisons.

In order to free the contact bodies from these harmful substances, the ordinary methods for removing them can, of course, be applied. The contact action can also be improved by heating contact metals which are inactive or of little use, owing to the presence of contact poisons, in the presence of oxygen or of bodies yielding oxygen. Or the metals can be heated, for instance, in the presence of oxygen, with the addition of suitable compounds, such as bases, and the resulting products reduced. These operations can be repeated if necessary. If more of such a body as mentioned is added than is necessary, it may act not merely by removing the poisons, but promote the yield, as I have already described to you.

On the other hand, it is necessary, as I remarked, to take the greatest care that nitrogen and hydrogen are free or freed completely from all contact poisons. Thus a trace of sulphur, one part per million, in the gas mixture can under certain conditions be injurious, so that even electrolytically-prepared hydrogen must generally be further specially purified. The minute purification of the gases is even more important when hydrogen prepared, for example, from the water gas is used. The impurities, too, taken up from iron

[4] "Synthetic Ammonia," H. A. Bernthsen, *Trans. Eighth Internat. Cong. Applied Chem.*, vol. xxviii, pp. 197–199.

piping play sometimes an important part, and impurities which get into the gases during the compression, such as machine oil, often have a harmful effect.

The best method of removing impurities from the gas mixture depends, in turn, on the nature of these impurities and consists, for instance, according to the case, in filtering, washing, conducting over solid absorption agents, and so on. One good method is to bring the gases into contact with the material of which the contact mass is prepared at a raised temperature, before passing them over the actual catalyst. The material takes up the impurities, and must, of course, be renewed from time to time. The negative results of earlier investigators in the formation of ammonia when using base contact metals (Wright, Ramsay and Young, and, more recently again, 1911, Neogi and Adhicary), according to which nitrogen and hydrogen do not combine in the presence of iron, are, in my opinion, probably due, for the most part at least, to the use of metals or gases not free from contact poison. That previous inquirers had not the remotest idea that sulphur in the contact metal could be injurious is evident from the fact that they passed the gases without hesitation through concentrated sulphuric acid in order to dry them. The sulphuric acid thus taken up and the sulphur dioxide often contained in it can poison even the best catalyst very speedily and render it unfit for use. Or the contact metals were sometimes prepared directly from the sulphates, although a metal sufficiently free from sulphur can scarcely be obtained by this method.

A painstaking study, for which we are indebted principally to Dr. A. Mittasch and which involved literally many thousands of experiments, has afforded an insight into the importance of substances of the most varied nature as promoters and poisons, and thus a sure foundation has been prepared for a reliable continuous manufacture with a good yield of ammonia.

This is a wonderful story that has been here set forth, and should show very clearly that modern warfare depends not alone upon the work of a general military and naval staff or upon the drilling and marshalling of millions, but, first and foremost, upon the systematic and painstaking researches of scientists, who, to use a homely expression, might be said to be twisting reluctant Nature's tail in the effort to make her march in the desired path.

IV.

THE RÔLE OF THE HALOGENS.

No description of the rôle of chemistry in modern warfare would be quite complete without some reference to the poisonous gases and flames with which modern armies seek to ruin and devastate one another. A vast amount of terrifying descriptive matter has appeared in the press accounts of the great war, but very little accurate scientific information on this awful contribution of chemistry has as yet been made available.

We may safely discount as untrue the extraordinary stories of soldiers asphyxiated and left standing or sitting rigidly in the positions in which they were overcome. It is possible that bombs have been hurled that set free prussic acid or the deadly cyanogen gas (CN), another form of fixed nitrogen. It is more probable, however, that the most deadly effects have been produced by the use of a group of very active chemical elements known as the halogens. By the name of "halogens," meaning salt-formers, chemists distinguish the group of closely-allied elements, chlorine, bromine, and iodine. At ordinary temperatures and pressure, chlorine is a greenish-colored gas, bromine is a dark-red fuming liquid, and iodine is a beautiful violet-colored solid. At temperatures slightly above the ordinary bromine and iodine turn to heavy red and violet vapors. Chlorine is found in Nature fixed to the element sodium in common salt (sodium chloride). Sodium and other bromides are found accompanying common salt, while the principal source of iodine is seaweed, as marine growths have the power of collecting and concentrating iodides from salt water. It is characteristic of the halogens that they are among the most active chemical agents known. When in a free state they seem anxious to combine with anything they can take hold of, and the mucous membrane of the human throat, lungs, and eyes is peculiarly sensitive to their corrosive action. Chlorine gas, the most active of the family, is obtained in enormous quantities in the same way that hydrogen is, as a by-product from the electric process of manufacturing caustic alkali from common salt.

In the arts of peace chlorine has an important use as a bleaching agent in the paper and other industries. When compressed into steel cylinders, it can be liquefied and thus shipped from one point to another, or it can be absorbed in lime to form the well-known chloride of lime or bleaching powder. In war liquefied chlorine contained in steel shells can be burst among the enemy, and when the conditions are favorable terrible effects can thus be produced.

Bromine has never found any extended use in the peaceful arts, in spite of the fact that it has been stated that the German Government has been for a number of years offering a prize for the discovery of a practical use for it. Bromine is also a by-product material which has been largely allowed to escape in this

country, but which in Germany has been saved in increasing quantities for years.* In war bromine is even more terrible than chlorine, for it possesses the property of especially attacking the eyes, even producing blindness in large doses. If it comes in contact with the skin, it produces horrible burns which are slow to heal. When chlorine gas is allowed to come in contact with bromine under certain controlled conditions, they combine together to form a limpid fuming liquid, known as chloride of bromine, which combines the properties of both elements. It is said that this awful substance is the material that the warring nations have been hurling at each other in shells, bombs, and hand-grenades, although exact facts regarding these dreadful practices will probably not be available until after the war is over.

The rôle of iodine in the war is probably of a more kindly nature; it is not nearly so active an agent as the other two members of its family, and when dissolved in alcohol to make a tincture it has saved many lives on the battlefield when used as an antiseptic on open wounds

Some of the newspaper accounts have described gas bombs which exploded with dense violet fumes. If true, this points to the use of iodine also for this destructive purpose, but it is not probable that such a use is common, owing to the higher cost, greater scarcity, and limited activity of iodine as compared with the other halogens.

Much has also been written in regard to the masks or breathers

* Bromine.—Both technical and U. S. P. descriptions of this commodity continue in scanty supply and strongly held at a minimum of $5 by leading manufacturers, while maintained at $6 and even at $6.50 by second hands. Reports to the effect that the recent sharp uplift of prices for this article has been due to the operations of a syndicate of makers in Michigan, Ohio, Virginia, and West Virginia are not credited by those in a position to know, as it is obvious that the growing shortage, due to recent heavy sales on contracts to European users, is alone responsible for this upward movement of prices. Seemingly this extensive export movement of bromine can not be forbidden by the United States Government authorities or virtually prohibited by a high export tax, without enactment to this effect by Congress. Efforts to prevent further heavy shipments of this commodity to foreign countries have recently been made in vain by manufacturers of bromides who complained of this export movement to the Secretary of Commerce only to be referred to a special investigator in New York city, who informed him that the government was powerless to interfere with this business.—*Oil, Paint and Drug Reporter*, New York, Dec. 20, 1915, p. 44.

resorted to for protection from these dangerous gases. There are a number of chemical substances which are absorbents of chlorine and bromine and with which they can combine or fix themselves. Such chemicals spread between layers of fabric or liquids in which fabric masks can be soaked probably furnish such means as are available for protection.

CONCLUSION.

Besides the rôle of chemistry in war, the allied art of metallurgy plays an important part. New steels and alloys have to be devised, tested, and finally manufactured, suitable for the varied needs of war. Aëroplanes, dirigibles, and submarines all require materials with special physical characteristics. It is said that the metallurgists of Germany had to devise a new steel alloy before the Haber process for fixing nitrogen could be successfully worked on the large scale of operation. Space here does not permit of a description of these special metals, but perhaps enough has been said to give the reader a general purview of the rôle of chemistry in war.

Although it has been shown that chemistry is the handmaiden of war, and that this last great struggle is indeed a chemists' war, as Dr. L. H. Baekeland has recently so happily phrased it:[5]

> Do not imagine that this is the first chemical war. The art of killing and robbing each other became chemical the day gunpowder was invented; at that time, however, the existing knowledge of chemistry was just of pinhead size. Napoleon knew very well how to use adroitly exact knowledge and chemistry for furthering his insatiable ambition to dominate the world; so he surrounded himself with the most able chemical advisers and scientists. Ever since then science, technology, and chemistry in particular have played a rôle of increasing importance in the armament of nations. . . .
>
> Do not reproach chemistry with the fact that nitro-cellulose, of which the first application was to heal wounds and to advance the art of photography, was stolen away from these ultra-pacific purposes for making smokeless powder and for loading torpedoes. Do not curse the chemist when phenol, which revolutionized surgery, turned from a blessing to humanity into a fearful explosive, after it had been discovered that nitration changes it into picric acid.
>
> Let us hope, in the meantime, that war carried to its modern logical gruesomeness. shorn of all its false glamour, deceptive picturesqueness, and rhetorical bombast, exposed in all the nakedness of its nasty horrors, may hurry along the day when we shall be compelled to accept means for avoiding its repetition.

[5] "Chemical Industry," address by Dr. L. H. Baekeland before the American Chemical Society, Seattle, Wash., August 31, 1915.

Americans, North or South, probably without exception will join eagerly in the hope thus eloquently expressed, but in the meantime and under present conditions a strong, rich nation can no more exist without adequate means of self-defence than a modern city could exist without a trained police force and fire department. This paper has shown that fixed nitrogen is the first and most important element of national defence. The paper will have well served the author's purpose in preparing it if it should succeed even to a slight extent in calling attention to the necessity for purchasing and storing at a central point an adequate supply of Chilean nitrate. As an alternative, arrangements should be made which would have the effect of inducing capital to exploit in this country the fixation of atmospheric nitrogen. The fact that fixed nitrogen will become an increasingly important factor in the production of food simply means that, come peace or war, foresighted preparation will not under any circumstances be unprofitable or in vain.

The Flow of Air through Thin-plate Orifices. E. O. HICKSTEIN. (*Proceedings of the American Society of Mechanical Engineers,* December 7 to 10, 1915.)—That the problem of measuring large quantities of natural gas has not yet been solved will be conceded by most engineers familiar with the situation. During the past five years the rapidly-diminishing supply and consequent rise in price of this commodity have stimulated investigators to a closer study of its accurate measurement. Among the more important types of meters now used in measuring natural gas in large quantities may be mentioned proportional meters, pitot tubes, orifice meters, Venturi meters, rotary meters (on the anemometer principle), and electric (or calorimetric) meters. Due to the development of satisfactory differential gauges some years ago for recording small differences between two high static pressures, the last few years have seen a great increase in the number of pitot-tube and orifice-meter installations.

The orifice meter consists of a calibrated orifice disk in a pipe line with pressure line connections running to two indicating or recording gauges; one gauge is for measuring the static pressure of the flowing gas, the other the drop in pressure across the orifice. General formulæ for the flow through such orifices have been deduced and extensive tests made to determine the coefficients of discharge. About fifty orifice meters have been installed and are now in operation, and it is predicted that with further study and experimenting the orifice meter will rank among the most reliable methods of measuring natural gas in large quantities.

ON THE SINGLE-LINE SPECTRA OF MAGNESIUM AND OTHER METALS AND THEIR IONIZING POTENTIALS.*

BY

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I. INTRODUCTION.

It has been shown by Frank and Hertz[1] that when heated mercury vapor is traversed by electrons possessing kinetic energy slightly above that acquired in a fall of potential of 4.9 volts the vapor is stimulated to the emission of the single spectral line $\lambda = 2536.72$ Å. U. It has also been shown by McLennan and Henderson[2] that a spectrum consisting of this single line only can be obtained from mercury vapor when it is bombarded by electrons possessing energy corresponding to any fall of potential within a range beginning at about 5 volts and extending up to slightly over 10 volts. The investigation has also been extended by McLennan and Henderson to include a study of the radiation emitted by zinc and cadmium vapors when traversed by electrons. With these vapors they have found that single-line spectra can be obtained when the electrons traversing these vapors possess kinetic energy lying within a limited and clearly-defined range, which has not been fully investigated as yet, but which corresponds roughly to potential differences lying between 4 volts and 13.6 volts. With zinc vapor the single-line spectrum consists of light of wave-length $\lambda = 3075.99$ Å. U., and with cadmium vapor of light of wave-length $\lambda = 3260.17$ Å. U. It should also be pointed out here that the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. are respectively the first members of Paschen's[2a] combination series $\nu = 2, p_2 - m, S$, for the elements, mercury, zinc, and cadmium.

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* Presented at the meeting of the Section of Physics and Chemistry held Thursday evening, November 11, 1915.

[1] *Verh. d. Deutsch. Phys. Ges.*, vol. 11, p. 512 (1914).

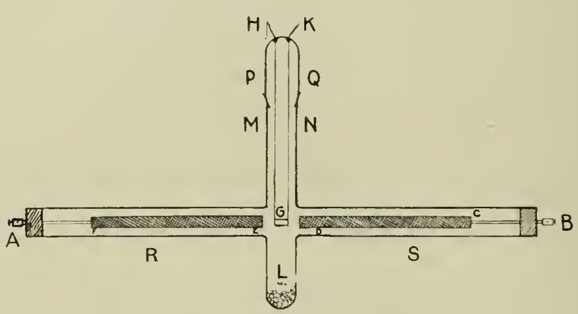
[2] *Proc. Roy. Soc. A.*, vol. 91, p. 485 (1915).

[2a] Paschen, *Ann. der Phys.*, No. 10, p. 869, 1911.

II. THE SINGLE-LINE SPECTRUM OF MAGNESIUM.

Since the publication of the results described above, the radiation from magnesium vapor traversed by electrons has been investigated by the writer, and it has been found with this element, too, that a single-line spectrum can be obtained if the electrons bombarding the vapor possess energy lying within a certain range whose limits also have not as yet been definitely determined, but which covers a portion at least of the ranges mentioned above for mercury, zinc, and cadmium. In carrying out these experiments the apparatus used and the procedure followed were precisely the same as those described in the paper by McLennan and Henderson. The form of arc used is that shown in Fig. 1. The apparatus consisted of a tube of fused quartz possessing

Fig. 1.

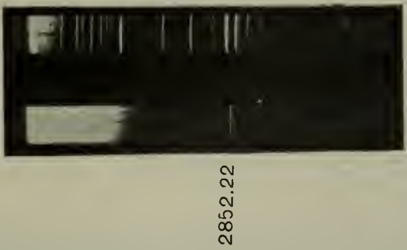


three arms, R, S, and MN, and a receptacle L. Some of the metal to be used in the arc was placed in the receptacle L, and two rods of the same metal, FE and DC, were attached to two wires, and these latter were in turn fastened to two brass plugs, A and B, which were sealed into the tubes R and S with mastic wax. A small piece of sheet platinum was attached to two wires which constituted the heating circuit, and these were sealed with platinum wire into a glass tube PQ at H and K. The open end of the glass tube PQ was ground so as to fit exactly into the end of the quartz tube MN, as shown in the diagram. The arms MN, R, and S were each about 40 cm. long and it was found with this length that when the receptacle L was strongly heated with a Bunsen burner the wax joints at A and B and the ground one at the end of the tube MN remained quite cool. In the experiments the plate G was coated with a thin layer of either cal-

cium oxide or barium oxide. When the tube was in operation the terminals of an auxiliary heating circuit were attached at H and K, B and K were joined by a wire, and the arcing voltage was applied between B and A, the latter being the positive terminal. With this arrangement G and D constituted a double cathode. The tube was highly exhausted with a Gaede mercury pump through a glass tube which was sealed into an opening in the brass end-piece at A.

In taking photographs the plate G was brought to incandescence by means of the auxiliary heating current, the metal in L was strongly heated with the flame of a Bunsen burner so as to keep the plate G surrounded with the vapor of the metal, and the collimator of a small spectrograph with a quartz train was directed at the incandescent plate G. A short tube of asbestos was

FIG. 2.



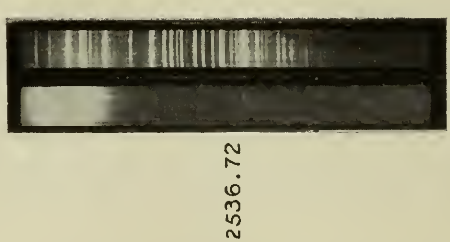
attached to the quartz tube directly in front of this plate so that the radiation from the arc passed through it to the slit of the spectroscope. This arrangement was found necessary in order to cut off the radiation from the Bunsen flame itself. It should be noted that in studying the radiation from mercury vapor the electrodes CD and FE were simply stout iron wires.

With the arrangement just described it was found that when the direct-current, 110-volt circuit, with suitable resistances in series, was applied to the terminals A and B, and the plate G brought to incandescence, strong arcs could be maintained for hours with mercury, zinc, or cadmium. With the 220-volt circuit applied the arcs of all three metals could be made most intense, and could also be maintained for long periods. With the 220-volt circuit it was found that, when the arc was once struck, it could be easily maintained for a considerable time without the continued use

of the oxy-cathode G. With low voltages, however, it was always necessary to maintain the plate G at incandescence in order to keep the arc established.

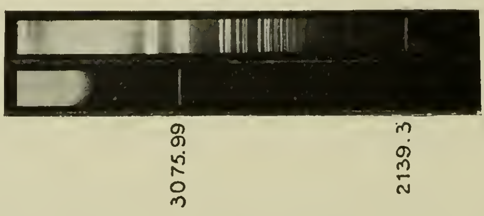
With magnesium the arcs could be maintained for short periods only and it was difficult to keep the vapor of the metal from condensing on the walls of the tube. The single-line spectrum of this

Fig. 3.



element consists of light of wave-length $\lambda = 2852.22$ Å. U. The ordinary spark spectrum of magnesium in air is shown in the upper row in Fig. 2, and the single-line spectrum of the vapor of the metal in the second row of the same figure. The latter was obtained with a three-hour exposure, and the electrons which stimulated the vapor to the emission of this radiation acquired their kinetic energy

Fig. 4.



with an arcing potential of 8.2 volts applied between the Wehnelt cathode and the positive terminal.

The single-line spectrum for mercury vapor which is shown in Fig. 3, at $\lambda = 2536.72$ Å. U., was obtained with an arcing potential difference of 9 volts with an exposure of two hours and a half. This single-line spectrum was also obtained with a potential fall of 5 volts, but it was only just visible on the plate with a five-hour exposure. With 3 volts and a five-hour exposure the line was not obtained. The line $\lambda = 3075.99$ Å. U., shown in

the lower spectrogram of Fig. 4, was obtained with zinc vapor and an arcing potential of 10.5 volts with an exposure of three hours, and the line $\lambda = 3260.17$ Å. U., shown in the lower spectro-

FIG. 5.

3260.17 2288.79

gram of Fig. 5, was obtained with cadmium vapor with an arcing potential difference of 13.6 volts. With an arcing potential of 3.4 volts and a three-hour exposure no trace of the line was obtained with this element.

III. THE ABSORPTION SPECTRA OF MAGNESIUM AND OTHER METALLIC VAPORS.

In a paper recently published by McLennan and Edwards[3] it has been shown that in the absorption spectrum of mercury there is an absorption band at $\lambda = 2536.72$ Å. U., and one at $\lambda = 1849.6$ Å. U. With this vapor it has been found that there is also a complex band obtainable at $\lambda = 2338$ Å. U., when high vapor densities are used. With zinc and cadmium vapors it has been shown by the same writers that the absorption spectra consist of but two absorption bands. With zinc vapor these are at $\lambda = 3075.99$ Å. U., and at $\lambda = 2139.3$ Å. U., and with cadmium vapor they are at $\lambda = 3260.17$ Å. U., and $\lambda = 2288.79$ Å. U. As pointed out above, the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. are the first members of Paschen's combination series for the three elements represented by $\nu = 2, p_2 - m, S$, and they are therefore the lines of this series corresponding to the value $m = 1.5$. Again, it will be seen, by referring to

[3] McLennan and Edwards, *Proc. Roy. Soc. of Canada*, 1915; *Phil. Mag.*, November, 1915.

Paschen's[4] paper, that the lines $\lambda=1849.6$ Å. U., $\lambda=2139.13$ Å. U., and $\lambda=2288.79$ Å. U. are the first members of the series $\nu=1.5, S-m, P,$ predicted by Paschen and later identified in part by Wolff[5] for the three elements mercury, zinc, and cadmium.

It does not appear, from communications which have come to the notice of the writer, that a series corresponding to $\nu=1.5, S-m, P$ has as yet been identified in the spectrum of magnesium, but if we assume that the line $\lambda=2852.22$ Å. U. is the first line in the combination series $\nu=2, p_2-m, S$ for this element, sufficient information is given in a paper by Dunz[6] to calculate the first and the last member of the series $\nu=1.5, S-m, P$ for this metal. In the paper by Dunz referred to, the frequency of $\nu=2, p_2$ in the magnesium spectrum is given as 39,793.21. If we take the frequency of the line $\lambda=2852.22$ Å. U. to be 35,050.45, it follows that the frequency $\nu=1.5, S$ is equal to 74,843.66. This will then be the frequency of the last line of the series spectrum of magnesium given by $\nu=1.5, S-m, P$. Again, in the paper by Dunz the frequency $\nu=2, P$ is given as 26,612.7, and from this it follows that the frequency of the first line in the series $\nu=1.5, S-m, P$ (*i.e.*, $\nu=1.5, S-2, P$) is 48,230.96. This, it will be seen, is the frequency of the line $\lambda=2073.36$ Å. U. If then the vapor of magnesium were to act, as regards absorption, in a manner analogous to the vapors of mercury, zinc, and cadmium, the absorption spectrum of magnesium vapor should contain absorption bands at $\lambda=2852.22$ Å. U. and at $\lambda=2073.36$ Å. U. On looking up the literature on the subject it was found that Wood and Guthrie[7] and Eder and Valenta[8] had already shown that there is an absorption band in this spectrum at $\lambda=2852.22$ Å. U., but, as no one seemed to have found any band at $\lambda=2073.36$ Å. U., some experiments were made to see if it really existed. The experiments confirmed its existence, and a reproduction of one of

[4] Paschen, *loc. cit.*

[5] Wolff, *Ann. der Phys.*, 1913, vol xlii, p. 525.

[6] Dunz, "Bearbeitung unserer Kenntnisse von den Serien," Inaug. Diss., Tübingen, 1911.

[7] Wood and Guthrie, *Astrophys. Jour.*, vol. xxix, No. 1, p. 211 (1909).

[8] Eder and Valenta, "Atlas Typischer Spectren," Table xxvii.

the photographs taken is shown in Fig. 6. The upper portion of this figure was taken with the light from the spark between magnesium terminals in air, and the lower one with the same light after it had traversed an evacuated clear fused quartz tube containing heated non-luminous magnesium vapor. As the reproduction shows, absorption occurred at $\lambda = 2852.22$ Å. U. and at $\lambda = 2073.36$ Å. U., as well. In addition, a narrow absorption band appears at $\lambda = 2536.72$ Å. U. This band also appeared in the experiments of McLennan and Edwards referred to above in the absorption spectrum of zinc and cadmium vapors, and it was no doubt due to a trace of mercury vapor which may have come from mercury originally present as an impurity in the metals or from mercury which got into the absorption tubes containing the vapors

FIG. 6.

FIG. 7.

when these tubes were exhausted by the Gaede mercury pump. From this result it will be seen that the absorption spectrum of magnesium vapor is exactly analogous to the absorption spectra of mercury, zinc, and cadmium. The analogy, moreover, between the absorption spectrum of magnesium and that of mercury is more perfect than would appear from the above considerations, for the absorption band at $\lambda = 2536.72$ Å. U., in the absorption spectrum of mercury vapor, comes out with small vapor densities as two narrow absorption bands whose wave-lengths have been given by R. W. Wood[9] as $\lambda = 2536$ Å. U. and $\lambda = 2539$ Å. U. The absorption band at $\lambda = 2852.22$ Å. U., in the absorption spectrum of magnesium vapor, has also been found to consist of two narrow, sharply-defined bands very close together. These are shown in the reproduction in Fig. 7, which was obtained by

[9] R. W. Wood, *Astrophys. Jour.*, vol. xxvi, No. 1, p. 41.

greatly enlarging a negative of the band in Fig. 6 at $\lambda = 2852.22$ Å. U. The bands at $\lambda = 3075.99$ Å. U. and $\lambda = 3260.17$ Å. U., in the absorption spectra of zinc and cadmium vapors, have not as yet been resolved into analogous doublets.

IV. THE SINGLE-LINE AND ABSORPTION SPECTRA OF CALCIUM, STRONTIUM, AND BARIUM VAPORS.

The attention of the writer was recently directed to papers by Charles De Watteville [10] on "Flame Spectra." In these papers the author has pointed out that the spectrum of the radiation from the cone of a flame fed by the spray of salt solutions of a number of elements consists in some cases of but a single strong line, and in others of a single strong line accompanied by a number of very much fainter ones.

These strong lines for the different metals are:

Magnesium	2852.22 Å. U.
Mercury	2536.72 " "
Zinc	3075.99 " "
Cadmium	3260.17 " "
Calcium	4226.91 " "
Strontium	4607.52 " "
Barium	5535.69 " "

De Watteville in his papers points out that these metals all belong to Mendelejeff's second group, and he also presents a number of considerations which led him to conclude that these lines are corresponding ones in the spectra of these seven metals. If we accept this conclusion it follows, from what goes before, that calcium, strontium, and barium vapors should emit single-line spectra of the wave-lengths just mentioned if bombarded by electrons possessing the requisite amount of energy. It also follows that absorption bands should appear in the absorption spectra of the vapors of these metals at the respective wave-lengths given above. The only information regarding the absorption spectra of these metals which the writer has been able to find is contained in the "Atlas of Spectra," by Eder and Valenta.[11] In Table XXII of this atlas a spectrogram is given of the arc spectrum of calcium which shows a strong reversal band

[10] De Watteville, *Phil. Trans. Roy. Soc.*, Series A, vol. 204, pp. 139–168 (1904), and C. R. No. 142, 1906.

[11] Eder and Valenta, *loc. cit.*

at $\lambda = 4226.91$ Å. U., but it also shows in addition faint reversals at $\lambda = 3934$ Å. U., $\lambda = 3936$ Å. U., $\lambda = 4440$ Å. U., and $\lambda = 4460$ Å. U. In the same table a spectrogram of the arc spectrum of strontium bromide also shows reversals at $\lambda = 4607.52$ Å. U. and $\lambda = 4078$ Å. U., and in Table XXIII a spectrogram of the arc spectrum of barium bromide shows reversals at $\lambda = 5535.69$ Å. U. and $\lambda = 4554$ Å. U. No direct investigation of the absorption spectrum of the vapors of these metals appears to have been made as yet, but experiments are now being made by the writer, and it is expected that some information on this subject will be soon forthcoming.

If the line spectra of calcium, strontium, and barium be analogous to those of mercury, zinc, cadmium, and magnesium, then the spectra of the first-named metals should each contain a series given by $\nu = 1.5, S - m, P$. Assuming that the lines $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., and $\lambda = 5535.69$ Å. U. are the first members of the series $\nu = 2, p_2 - m, S$, for calcium, strontium, and barium (*i.e.*, that they are given by $\nu = 2, p_2 - 1.5, S$), it follows that if $\nu = 2, p_2$ be known for the spectra of these elements then the frequencies represented by $\nu = 1.5, S$ can be calculated for them, and these would give the waves of shortest length in the series $\nu = 1.5, S - m, P$. Further, a knowledge of the values of $\nu = 2, P$ for the spectra of the three elements would then give the first members of the same three series.

From the paper by Dunz it will be seen that for the spectra of calcium and strontium the values $\nu = 2, p_2$ are respectively 34,-989.47 and 31,420.38. Taking the frequencies of the lines represented by $\nu = 2, p_2 - 1.5, S$ for calcium and strontium to be 23,-644.25 and 21,705.82, it follows that the frequencies of $\nu = 1.5, S$ for these two elements are respectively 57,733.72 and 53,126.2. These frequencies correspond to $\lambda = 1732.1$ Å. U. and $\lambda = 1882.3$ Å. U., and these wave-lengths, therefore, should be the limiting ones in the series $\nu = 1.5, S - 2, P$ for the two elements mentioned. Again, the frequencies $\nu = 2, P$ for calcium and strontium are given in the paper by Dunz[12] as 27,510.2 and 25,745.2, so that,

[12] Dunz, *loc cit.*

combining these with the values of $\nu = 1.5, S$ given above, we have 30,223.52 and 27,380.9 as the frequencies represented by $\nu = 1.5, S-2, P$ in the spectra of calcium and strontium. As the wave-lengths corresponding to these frequencies are $\lambda = 3308.6$ Å. U. and $\lambda = 3652.2$ Å. U., it would follow that these wave-lengths are respectively the first members of the series $\nu = 1.5, S-m, P$ in the spectra of calcium and strontium. The paper by Dunz does not appear to contain data which would enable one to determine the frequency $\nu = 2, P$ for barium. However, it gives the frequency $\nu = 2, p_2$ as 29,350.4 for this element. Taking then the wave-length $\lambda = 5525.69$ Å. U. as the one whose frequency is given by $\nu = 2, p_2 - 1.5, S$ in the spectrum of barium, it follows that for this element the frequency $\nu = 1.5, S$ is equal to 47,-414.99. As this is the frequency of $\lambda = 2109.04$ Å. U., it would appear that for barium this wave-length is the shortest one in the $\nu = 1.5, S-m, P$ series. From the considerations presented it would appear, therefore, that for calcium, strontium, and barium $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., and $\lambda = 5535.69$ Å. U. are respectively the first members of the series $\nu = 2, p_2 - m, S$, and that for the same elements $\lambda = 1732.1$ Å. U., $\lambda = 1882.3$ Å. U., and $\lambda = 2109.4$ Å. U. are respectively the last members of the series represented by $\nu = 1.5, S-m, P$. In addition, the first member of the series $\nu = 1.5, S-m, P$, in the spectrum of calcium should be $\lambda = 3308.6$ Å. U., and the first member of the same series for strontium, $\lambda = 3652.2$ Å. U. The information regarding the details of the series spectra of barium at present available is not sufficient, apparently, to enable one to calculate the wave-length of the first member of the series $\nu = 1.5, S-m, P$ for this element.

As the absorption spectra of the vapors of mercury, zinc, cadmium, and magnesium have absorption bands at the two wave-lengths given by $\nu = 2, p_2 - 1.5, S$ and $\nu = 1.5, S-2, P$, it would follow, from the arguments presented, that if the vapors of calcium, strontium, and barium behave in an analogous manner there should be absorption bands at $\lambda = 4226.91$ Å. U. and $\lambda = 3308.6$

Å. U. in the absorption spectrum of calcium vapor, and also bands at $\lambda = 4607.52$ Å. U. and $\lambda = 3652.2$ Å. U. in the absorption spectrum of strontium vapor. The absorption spectrum of the vapor of barium should contain a band at $\lambda = 5535.69$ Å. U., but, as previously stated, the information available is not sufficient to predict the position of the second absorption band.

As already pointed out above, we have sufficient information available already regarding the absorbing properties of calcium, strontium, and barium vapors to confirm in part the findings just presented, but to confirm them fully additional experiments will have to be made.

V. THE SINGLE-LINE AND ABSORPTION SPECTRA OF THALLIUM.

Ramage,[13] in a paper on the comparative study of the spectra of some of the elements, points out that the flame spectrum of thallium also consists of the single line $\lambda = 5350.65$ Å. U. If we assume, as we have done in dealing with the single-line flame spectra of calcium, strontium, and barium, that the frequency of the line $\lambda = 5350.65$ Å. U. is that of the first line in the series $\nu = 2$, $p_2 - m$, S for the spectrum of thallium (*i.e.*, that it is given by $\nu = 2$, $p_2 - 1.5$, S), then, since for this element Dunz gives the frequency $\nu = 2$, p_2 as 49,262.55, it follows that the frequency $\nu = 1.5$, S for the spectrum of thallium is equal to 67,946.77. This frequency corresponds to the wave-length $\gamma = 1471.74$ Å. U., and this wave-length should, therefore, be the last one in the series $\nu = 1.5$, $S - m$, P of the spectrum of the element thallium.

As the frequency $\nu = 2$, P is not known for the spectrum of thallium, one is not able as yet to calculate the frequency $\nu = 1.5$, $S - 2$, P (*i.e.*, the frequency of the first line in the series $\nu = 1.5$, $S - m$, P).

If we assume the behavior of thallium vapor as regards absorption to be the same as that of the vapor of mercury, zinc, cadmium, and magnesium, we should expect to find absorption bands in its absorption spectrum at the wave-lengths given by the frequencies $\nu = 2$, $p_2 - 1.5$, S and $\nu = 1.5$, $S - 2$, P.

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[13] H. Ramage, *Proc. Roy. Soc.*, vol. 70, p. 1 (1907).

Wood and Guthrie, in their paper on the absorption spectra of metallic vapors, state that with thallium they found a strong absorption band at $\lambda = 2380$ Å. U., and fainter ones at λ 3230 Å. U., $\lambda = 3092$ Å. U., and $\lambda = 2530$ Å. U., but they do not seem to have found any indication of absorption at $\lambda = 5350.65$ Å. U., which is the wave-length whose frequency is given by $\nu = 2, p_2 - 1.5, S$. It is just possible that it would require high vapor densities and high resolving power to bring out this band, for in the case of zinc vapor it was found necessary to work under these conditions to bring out the absorption band at $\lambda = 3075.99$ Å. U.

VI. THE IONIZING POTENTIALS OF DIFFERENT ELEMENTS.

In the paper by McLennan and Henderson attention was drawn to a paper by Frank and Hertz [14] which described experiments leading to the conclusion that the minimum energy required to ionize an atom of mercury was that acquired by an electron in passing through a fall of potential of 4.9 volts. Attention was also drawn in this paper to a second communication by Frank and Hertz [15] in which it was shown that in the quantum relation $Ve = h\nu$ where $h = 6.6 \times 10^{-27}$ erg sec. 4.9 volts is the potential fall which corresponds to the frequency of the line $\lambda = 2536.72$ Å. U. From this it follows that for mercury atoms at least a knowledge of the wave-length of the single line characterizing the single-line spectrum of this element is sufficient to enable one to calculate the ionizing potential. If the relation just pointed out be applicable generally to all the elements, it follows that if the vapor of an element can be shown to be capable of exhibiting a single-line spectrum the frequency of this single spectral line may be used to deduce the minimum amount of energy required to ionize the atoms of that element. From the considerations already presented in this paper it will be seen that the wave-lengths of the single spectral lines in the single-line spectra of the elements have the frequencies given by $\nu = 2, p_2 - 1.5, S$, and, as these frequencies are known for mercury, zinc, cadmium,

[14] Frank and Hertz, *Vehr. d. Deutsch. Phys. Ges.*, vol. 10, pp. 457–467, 1914.
[15] Frank and Hertz, *Ibid.*, vol. 11, p. 512, 1914.

magnesium, and probably also for calcium, strontium, barium, and thallium, it follows that if Frank and Hertz have put the correct interpretation upon their experiments—and it may be added here that their experiments have apparently been confirmed quite recently by Newman [16]—then the ionizing potentials for the atoms of all these elements can be calculated by the relation $Ve = h\nu$. The results of this calculation are given in Table I.

TABLE I.

Element	Wave-length with frequency $\nu = 2, p_2 - 1.5, S$	Ionizing potential calculated on basis of conclusions of Frank and Hertz
Mercury	2536.72 Å. U.	4.9 volts
Zinc	3075.99 " "	3.96 "
Cadmium	3260.17 " "	3.74 "
Magnesium	2852.22 " "	4.28 "
Calcium	4226.91 " "	2.89 "
Strontium	4607.52 " "	2.65 "
Barium	5535.69 " "	2.24 "
Thallium	5350.65 " "	2.28 "

In the paper by McLennan and Henderson it was pointed out that in order to obtain the single-line spectra with mercury, zinc, and cadmium vapors it was necessary that the electrons bombarding these vapors should not possess kinetic energy greater than that acquired in passing through falls of potential of 12.5 volts, 11.8 volts, and 15.3 volts respectively for the three vapors. If the electrons possessed kinetic energy greater than that given by these voltages, visible arcs were struck and the many-lined spectra were obtained for the three elements. In the paper mentioned it was also stated that as these voltages gave with the relation $Ve = h\nu$ approximately the wave-lengths of the limiting lines in the series $\nu = 1.5, S - m, P$ for the three elements, the results might be interpreted as indicating possibly a second type of ionization which the atoms of these elements might be capable of undergoing. If this interpretation should turn out to be correct, it would follow, since the frequency of the limiting lines in the series $\nu = 1.5, S - m, P$ are given by $\nu = 1.5, S$, that the ionizing potentials of the second type are given by $V = h \times (1.5, S)/e$. Applying this relation to the results already obtained and

[16] Newman, *Phil. Mag.*, **28**, pp. 753–756, November, 1914.

given above, the ionizing potentials of the second type have been calculated for mercury, zinc, and cadmium, magnesium, calcium, strontium, barium, and thallium, and are given below in Table II.

Table II.

Element	Wave-length corresponding to frequency $\nu = 1.5, S$	Ionizing potentials calculated from $V = h \times (1.5, S)/e$
Mercury	1188.0 Å. U.	10.27 volts
Zinc	1320.0 " "	9.24 "
Cadmium	1378.7 " "	8.85 "
Magnesium	1336.1 " "	9.13 "
Calcium	1732.1 " "	7.04 "
Strontium	1882.3 " "	6.48 "
Barium	2109.04 " "	5.78 "
Thallium	1471.74 " "	8.29 "

VII. IONIZING POTENTIALS AND BOHR'S THEORY OF THE ORIGIN OF RADIATION.

In the theory which has been brought forward by Bohr [17] the atom of an element is supposed to consist of a positive Rutherford nucleus surrounded by one or more rings of electrons revolving in stationary or non-radiating orbits about the nucleus. In the neutral or most stable state the electrons are revolving in the orbits of smallest possible area. The diagram in Fig. 8 may be taken to illustrate this point.

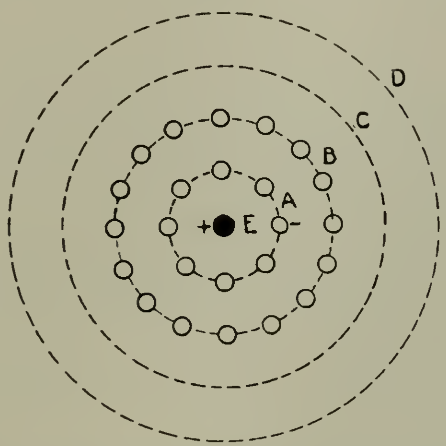
A neutral atom may be supposed, for example, to consist of a positive nucleus E surrounded by two rings of revolving electrons A and B. If through some agency, such as an electronic bombardment, one or more of the electrons in the ring B be made to revolve in the orbit C, then, according to the theory of Bohr, these electrons would not radiate while revolving in the orbit C, but they would send out a radiation of a single determinate wave-length in passing back from the orbit C to the stable orbit B. Extending the theory still further, if the disturbing agency caused one or more of the electrons in the orbit B to revolve in the orbit D, then, as the electrons might drop back either directly to the orbit B or to the orbit C first and then to the orbit B, it would appear that atoms subjected to such a disturbance would be capable, in returning to the neutral state, of emitting a radia-

[17] Bohr, *Phil. Mag.*, 26, pp. 1, 476, 857 (1913); 27, p. 506 (1914); 30, p. 394 (1915).

tion consisting of two and possibly three definite and determinate wave-lengths. It would then seem, from Bohr's theory, that atoms of a vapor bombarded by electrons should be capable of emitting either a single-line spectrum, a two- or three-line spectrum, a four-line spectrum, etc., according to the violence of the shock to which they were subjected.

Again, according to the theory of Bohr, ionization of an atom could only be said to have taken place when the disturbing agency caused one or more of the electrons to be projected out from the electronic system beyond the outermost stationary or non-radiating orbit of the atom. This theory would, therefore,

FIG. 8.



predicate but one type of ionization for atoms. By applying the theory to the matters discussed in the present communication it would appear that atoms in the state to emit a single-line spectrum could not be said to be ionized. It would follow then that if Bohr's theory of the origin of radiation be correct, the interpretation placed by Frank and Hertz on the results of their direct investigation of the ionizing potentials for mercury atoms cannot be the correct one. On the other hand, in the experiments of Henderson and myself in which the single-line spectra were obtained with mercury, zinc, and cadmium vapors when they were bombarded by electrons, the fields in which these bombarding electrons acquired their energy covered a range of from about 5 volts to slightly over 10 volts. It is probable that under

these conditions the great majority of the bombarding electrons would acquire just sufficient energy to stimulate the atoms of the vapors traversed to the emission of a radiation of but a single wave-length. The second absorption bands, however, in the absorption spectra of mercury, zinc, and cadmium vapors, it will be recalled, come at $\lambda = 1849.6$ Å. U., $\lambda = 2139.3$ Å. U., and $\lambda = 2288.79$ Å. U. respectively, and it will be seen, therefore, that if the quantum relation $Ve = h\nu$ be applicable the potential falls corresponding to these wave-lengths are well within the range extending from 5 to 10 volts. One would have expected, therefore, that with arcing potentials of 10 volts one should have found traces at least of the lines $\lambda = 1849.6$ Å. U., $\lambda = 2139.3$ Å. U., and $\lambda = 2288.79$ Å. U. acompanying the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. in the spectra emitted by the three vapors. No indication of these lines, however, was found in the experiments of Henderson and myself, even with exposures of five hours' duration and with vapors covering a wide range of densities. It should be remembered that, even if some of the atoms of the vapors traversed were stimulated to the emission of the shorter wave-lengths mentioned, the radiation of these wave-lengths might have been absorbed in passing through the outer layers of the vapor in the arcing tube. The experiments of Henderson and myself cannot, therefore, be taken as being opposed to the correctness of Bohr's theory. If, however, this theory be correct, then it does follow that Frank and Hertz have incorrectly interpreted their results. Moreover, if it should turn out that they and also Newman have placed the wrong interpretation on the results of their investigations, then the ionizing potentials for mercury, zinc, cadmium, magnesium, calcium, strontium, barium, and thallium should not be those given in Table I, but they should, in all probability, be those given in Table II, and we should arrive at the conclusion that there is but one type of ionization for atoms.

VIII. SUMMARY OF RESULTS.

1. It has been shown that, like the vapors of mercury, zinc, and cadmium, magnesium vapor, when traversed by electrons, can be stimulated to the emission of a single-line spectrum. The wave-length of this line is given by $\lambda = 2852.22$ Å. U.

2. It has been shown that the absorption spectrum of non-luminous magnesium vapor contains an absorption band at $\lambda = 2852.22$ Å. U. and one at $\lambda = 2073.36$ Å. U.

3. As the lines $\lambda = 2852.22$ Å. U. and $\lambda = 2073.36$ Å. U. are the first members of the series $\nu = 2, p_2 - m, S$ and $\nu = 1.5, S - m, P$ respectively, the absorption spectrum of magnesium vapor has been shown to be analogous to the absorption spectra of the vapors of mercury, zinc, and cadmium.

4. Considerations have been presented which indicate that the single-line spectra of calcium, strontium, barium, and thallium vapors under bombardment by electrons should have the wave-lengths $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., $\lambda = 5535.69$ Å. U., and $\lambda = 5350.65$ Å. U. respectively.

5. The ionizing potentials have been deduced for atoms of magnesium, calcium, strontium, barium, and thallium in addition to those for the atoms of mercury, zinc, and cadmium.

6. Considerations have also been presented which show that if Bohr's theory affords an explanation of the origin of single-line spectra, then Frank and Hertz and also Newman must have placed a wrong interpretation on the results of their direct investigation of the ionizing potentials for mercury atoms.

University of Toronto,
November 11, 1915.

Turbines vs. Engines in Units of Small Capacities. J. S. BARSTOW. (*Proceedings of the American Society of Mechanical Engineers,* December 7 to 10, 1915.)—It may safely be said that not until twenty years ago was there any really reliable steam turbine developed, and even as late as ten years ago the turbine was looked upon mainly as an experiment. The last few years, however, have witnessed the practical perfection of this type of prime mover in sizes as large as 50,000 horse-power, with units of 30,000 horse-power quite common in central stations, and for installations of such enormous output the superiority of the turbine is undisputed. In small plants of 500 horse-power or less the turbine still divides honors with the reciprocating engine, and in the present state of the art a judicious selection between them can only be made by a close analysis of all the requirements and by comparing the costs of meeting them with each type of prime mover.

A Mode of Studying Damped Oscillations by Means of Shrinking Vectors. D. ROBERTSON. (*The Journal of the Institute of Electrical Engineers,* vol. 54, No. 251, December 1, 1915.)—The application of rotating vectors to sine waves has proved of very great service in connection with the theory of alternating currents. It has made it possible to form simple mental pictures of the phase relationships, and has facilitated the deduction of formulæ by which calculations can be made. It also allows us to obtain graphical solutions of problems, but this is of less value than the two uses just mentioned.

Damped oscillations can be represented in a similar manner by means of shrinking vectors, and the equations for such oscillations can be deduced from such vectors almost as easily as those for ordinary alternating currents. The vector diagrams bring the theory of the subject completely within the grasp of those to whom the differential and integral calculus are profound mysteries. In fact, the vector method is a valuable means of differentiating and integrating sine functions in a simple manner without any knowledge of the calculus. Even to the mathematician the vector diagram is useful, for it gives a valuable picture of the phase relationships, which permits the equations being written down straight away so as to fulfil the initial conditions, instead of being written first with unknown constants whose values have to be afterwards found from these conditions. The paper is written mainly from the point of view of electrical oscillations, but the method is equally applicable to any kind of vibration.

Una-flow Steam Engines for Electric-plant Operation. ANON. (*Electrical World,* vol. 67, No. 1, January 1, 1916.)—Some very excellent results are announced in the performance of the so-called "una-flow" steam engine. In this engine the exhaust takes place at the end of the stroke through a port in the middle of the cylinder opened and closed by the passage of the piston over it. By this arrangement a constant temperature at any given point of the cylinder is maintained, thus reducing the losses by condensation occurring in other types of engine in which the live and exhaust steam are alternately in contact with the same part of the cylinder.

A una-flow engine built under the Stumpf patents by the Ames Iron Works, Oswego, N. Y., has been installed in the Quitman (Ga.) municipal lighting plant. This is a simple condensing engine with a cylinder 20 inches in diameter and a stroke of 22 inches. It develops about 400 horse-power at 200 revolutions per minute, with a pressure of 165 pounds per square inch, 26-inch vacuum, and steam superheated 100° F. In a test under these conditions, this engine showed a steam consumption of 12.4 pounds per indicated horse-power per hour at one-quarter load, 11.5 pounds at half load, 11.2 pounds at three-quarters load, 11.6 pounds at full load, and 12.5 pounds at 25 per cent. overload. Tests on other engines of the same type are reported as giving substantially similar results.

ARCS IN GASES BETWEEN NON-VAPORIZING ELECTRODES.*

BY

G. M. J. MACKAY

AND

C. V. FERGUSON.

The object of this note is to indicate the nature of some experiments, to be more fully described later, made during an investigation of the rectifying properties of gases, which tend to throw some light upon arc phenomena and gaseous conduction in general.

The work of Dr. Langmuir[1] upon the emission of electrons from an incandescent filament in vacuum has been extended and applied in the field of electrical conduction through gases at comparatively high pressures.

By the use of tungsten electrodes it has been found possible to construct enclosed arcs which will act as rectifiers of alternating current, and carry 10 to 20 ampères with such slight deterioration of the metal that a life of many hundreds of hours may be obtained. The electrodes operate at temperatures between 2600° and 3200° K., and there appears to be no more loss of material than can be accounted for by the normal rate of evaporation of the tungsten at these temperatures. That this is extremely small is evidenced by the life of the filament in the nitrogen-filled lamp, which operates at about 2800° K. where the vapor pressure is about 3.10^{-5} mm.,

TABLE I.

Temperature, °K.	Vapor pressure, mm.	Rate evap. g. sq. cm. s.	Thermionic current, ampères	Molecules of H_2 per c.c. capable of ionizing
2000	645.10^{-14}	114.10^{-15}	.004	1
2400	492.10^{-10}	798.10^{-12}	.365	10^4
2800	286.10^{-7}	429.10^{-9}	8.98	10^6
3200	333.10^{-5}	467.10^{-7}	96.9	10^8
3540 M.P.	80.10^{-3}	107.10^{-5}	509	10^9
5100 B.P.	760.	....	57023	10^{12}

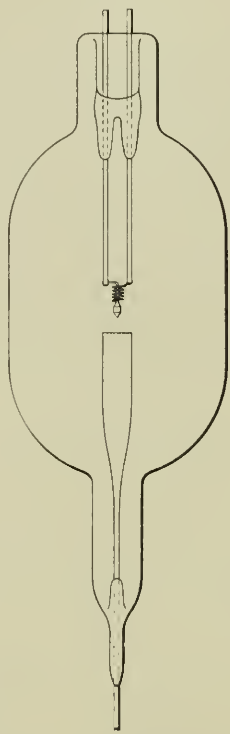
as shown in Table I. There is also some reason for believing that the evaporation is less than would occur due to the high temperature alone, since such tungsten as is evaporated seems to be carried

* Communicated by Dr. Whitney.

[1] *Physical Review*, N. S., ii, p. 450 (1913).

within the arc stream from the anode to the cathode on direct current. If the pressure of the gas be of the order of several centimetres or higher, there is no trace of the so-called "cathode sputtering" which occurs so violently at lower pressures. The reasons for the absence of this effect seem to be: (1) elimination of high cathode drop by a uniformly highly-heated electrode, (2) a comparatively high pressure of gas which lowers the cathode drop

FIG. 1.

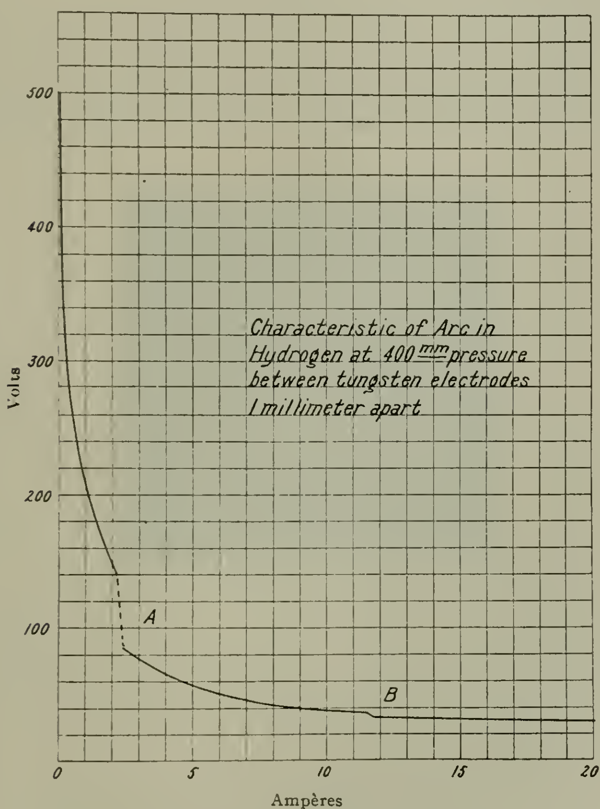


by lessening the mean free path of the impinging positive ions and also lowers the rate of evaporation of the hot metal, as in the case of the filament of the gas-filled lamp.

A typical piece of apparatus used in the investigation is shown in Fig. 1. In order to study the effect of temperature at the cathode this electrode is supplied with a tungsten filament requiring about 20 ampères to heat it to 2800° K. The anode is made large so that it will operate at a comparatively low temperature.

Fig. 2 shows the volt-ampère characteristic of hydrogen as found on direct current with such an arrangement. It will be seen that it has the typical form described by Dr. W. G. Cady,[2] showing an unstable portion at *A*, where the discharge changes with increasing current from an almost invisible glow to a very concen-

FIG. 2.



trated arc discharge, and a less noticeable "kink" at *B*. Other gases, such as nitrogen and argon, however, do not show such well-defined points of instability. A photograph of a similar arc with a longer gap of 6.6 mm. is shown in Fig. 3. The appearance of this arc is very striking; though very thin and of little luminosity, the path is very clearly defined. The energy consumption is also

[2] *Met. and Chem. Eng.*, xiii, p. 866 (1915).

very high, due doubtless to the fact of its more or less complete dissociation into atoms at the temperature involved, and its extremely good thermal conductivity. Thus the arc of Fig. 2, 1 mm. long and 0.5 mm. diameter, consumes 700 watts, operating at 25 ampères and 28 volts. It should be a very good source of ultraviolet radiation.

If the characteristics of the arc are affected to any extent by the evaporation of electrode material, as has been supposed with carbon and low boiling-point metal electrodes, where the vapor pressure of the substance often reaches atmospheric pressure, it should be expected that strikingly different results would be ob-

FIG. 3.

Arc in hydrogen between tungsten electrodes 6.6 mm. apart.

tained with the tungsten arc. Since such differences have not been found, and since many arcs have shown no spectroscopic evidence of the presence of tungsten in the arc stream, it would appear that rapid evaporation plays no necessary part in the conduction of current.

On direct current the nature of the anode, whether large or small, of copper, carbon, or iron, does not appreciably affect the electrical characteristics.

The most interesting and most important phenomena occur at the cathode, which may take the form of a filament as shown above, capable of being heated to various temperatures by an external source of energy. In order for a discharge to have the typical " falling " volt-ampère characteristic shown in Fig. 2, it is necessary that the cathode spot be heated to a comparatively high tem-

perature, approximately 2800° K., either by the application of energy from without or by bombardment of positive ions from the gas.

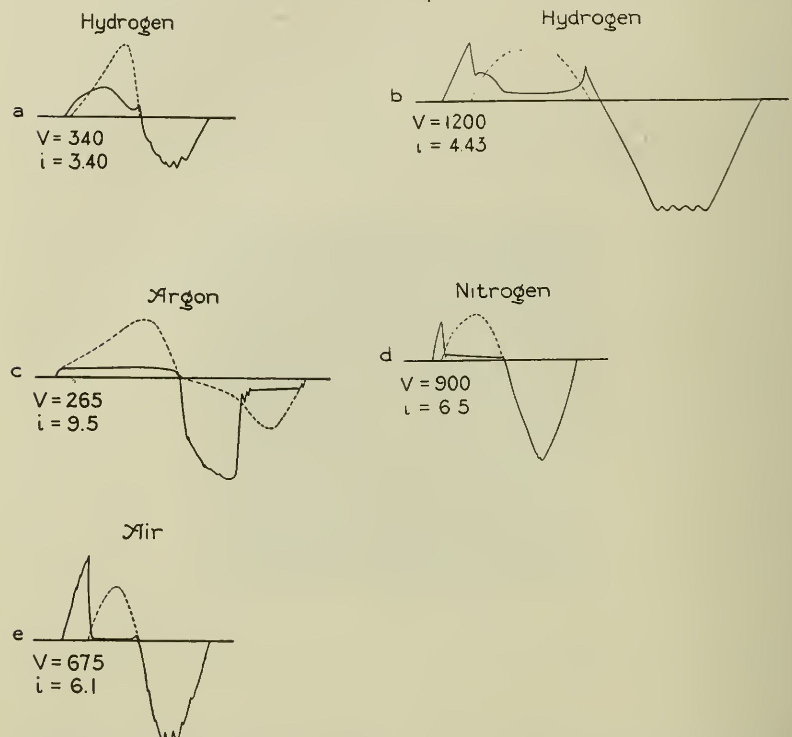
The chief function of a cathode heated from an external supply is the great reduction in sparking or arcing potential, which enables the discharge to be started at a voltage relatively very low in comparison with that necessary between cold electrodes. For instance, an arc in hydrogen with a 1 mm. gap will start on 400 volts if the cathode be heated, whereas with a cold electrode a voltage in the neighborhood of 4000 is required. Once the arc has started, the exciting current may be shut off from the filament, when the discharge will run with very little increase in voltage and maintain its own cathode spot at the proper temperature. The tungsten button in Fig. 1 offers a good design for this purpose, since the " spot " may be removed from the more fragile filament. With lower pressures, of course, much less voltage will start the arc over much wider gaps, and hence the bringing of the electrodes together to strike an arc is obviated and the advantage of a fixed gap length secured.

Fig. 4*c* illustrates these characteristics very well when an arc on alternating current is maintained between a tungsten cathode small enough to be kept hot by the discharge and an anode large enough to operate at a much lower temperature. These wave shapes were determined by oscillograph in argon at 20 cm. pressure. They show how the voltage necessary to start the arc from the hot cathode is no greater than the arc drop itself, whereas on the other half of the cycle, though there is a slight current from the beginning, the anode does not act like the hot cathode until the voltage has reached the peak of the wave. As the anode is allowed to heat, however, this " arcing back " voltage gradually decreases. This current obtained at the beginning of the half cycle when the large electrode is negative is probably due to persistence of the ionization produced during the first half of the wave. It is in sharp contrast to the complete rectification shown in Fig. 4*b*, where the rise of potential at the end of the cycle and the sharp " cut off " indicates a rapid recombination of ions due to their greater rate of diffusion in hydrogen.

Various gases show different characteristics. Fig. 4 shows typical curves for arcs in hydrogen, argon, nitrogen, and air. All give complete rectification of current under proper conditions. It

will be seen that in one case with hydrogen the initial part of the discharge has a positive volt-ampère characteristic, and that there is not the sudden drop from a peak voltage as in the case of most of the others. The last two cases are of interest because there is a chemical reaction occurring between electrodes and the gas with

FIG. 4.



Instantaneous (60-cycle) volt —— ampère - - - - - - characteristics of arcs in different gases. Effective values of volts and ampères.

the formation of volatile compounds of tungsten. With nitrogen there is apparently a film of nitride formed which slowly distils off, since tungsten nitride is formed in gas-filled lamps.[3] It has been thought by some that chemical reaction aids materially in the formation of an arc, but in these cases such conditions are certainly much less favorable than with the "inert" gases, argon and hydrogen.

[3] I. Langmuir, *Journ. Am. Chem. Soc.*, xxxv, p. 931 (1913).

In fact, in the case of argon, when very carefully purified, a total arc drop at 5 centimetres pressure is obtained that is less than 4 volts, which is considerably less than the ionization potential of 12 volts determined by Frank and Hertz.[4] The arc drop in the gas itself also appears to be less than ½ volt per centimetre.

This effect of reacting gases, such as nitrogen, oxygen, etc., on the starting of the above arcs, is very similar to the inhibiting effect on electron emission found by Langmuir.[5]

From the standpoint of rectification, interesting differences occur at different pressures. For instance, while hydrogen rectifies as well if not better at high pressure than at a few millimetres, argon, under the same conditions, seems to operate much better at pressures less than 10 centimetres. This seems to be due to a sudden change in the character of the discharge which occurs at about 12 centimetres, when the diffuse arc which exists at the lower pressure goes over into a more concentrated form with a small anode spot. This type of discharge apparently liberates heat at the anode so locally that "arc back" occurs at relatively low voltages on alternating current.

From the foregoing it would therefore appear that rapid vaporization and chemical reaction at the electrode surfaces are merely incidental to the physical phenomena involved, which are undoubtedly the most important.

Effects which must be considered are: (1) thermionic emission from the hot cathode, (2) thermionic emission from the hot gases, (3) effect of temperature on the gas to increase the kinetic energy of the molecules so that ionization may be produced by impact as suggested by J. J. Thomson, and (4) secondary electron emission from the hot cathode due to bombardment by positive ions.

Dr. Langmuir has shown that Richardson's equation for the current emitted by an incandescent body holds for tungsten at all temperatures, and has determined the constants as follows:

$$i = 23.6 \times 10^6 \sqrt{T}\, e^{-\frac{52,500}{T}}$$

Now these currents cannot be attained in high vacuum without employing very high voltage, on account of the mutual repulsion

[4] *Ber. d. deutsch. Phys. Ges.*, 15, p. 34 (1913).

[5] *Loc. cit.*

of the similarly-charged particles. This "space charge," however, is destroyed in gases by the positive ions produced by collision, so that the maximum electron emission may be realized at low voltages.

Below are tabulated the vapor pressure and the rate of evaporation in grammes per square centimetre per second of tungsten at different temperatures, the thermionic current as calculated by the above equation, and the number of molecules of hydrogen per cubic centimetre, which possess a kinetic energy corresponding to the ionization potential of 11 volts, calculated from the average kinetic energy of the molecule and Maxwell's distribution law.

The rate of evaporation of tungsten in an inert gas at atmospheric pressure is about 1 per cent. of the value in vacuum given above.

The currents obtained in practice are several-fold the normal thermionic emission, but, as the temperature of the gas is undoubtedly very high, it may be highly thermionic, so that with secondary electron emission it is not surprising that high conductivity of the different media exists. Thermal agitation of the gas is apparently too small to account for any great conductivity, though at the temperatures which may be involved its influence may be far from negligible.

It is hoped in the near future to publish a more quantitative study of these arcs, and to give data regarding the electrode drops in different gases under various conditions. The tungsten arc offers a very good opportunity for this, because by an optical pyrometer the temperature distribution of well-defined electrodes can be measured, consequently the watts radiated and conducted determined from existing lamp data, and so the electrode drops determined from the relationship

$$W = V \times I$$

the current being, of course, constant. The application of such arcs will also be discussed from the following viewpoints: high-frequency generators, rectifiers, and spectra of gases under different electrical conditions.

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THE APPLICATION OF THE PAPER PULP FILTER TO THE QUANTITATIVE ESTIMATION OF CALCIUM AND MAGNESIUM.*

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INTRODUCTION.

THE elements calcium and magnesium play a great rôle not only in the mineral kingdom, but also in the organic world, since they are absolutely indispensable to both the vegetable and animal cell. The importance of calcium ions for the life phenomena of the cells is easily comprehended when we consider that calcium is contained in bones, muscles, brain, blood, and the glands of animals, as well as in the membrane of plants; that calcium facilitates the transportation of carbohydrates in plants and precipitates the toxic oxalic acid in cells, and so forth.

The magnesium salts, too, display a variety of functions which have been studied, especially in their relation to the functions of calcium. Ever since Ringer [1] has shown that the toxic effect of potassium can be paralyzed by means of calcium, the question of the antagonism between calcium and magnesium, as well as between various salts generally speaking, is being studied and discussed by a number of investigators. Osterhout,[2] *e.g.*, has demonstrated that the toxic action of pure sodium chloride solution on algæ can be inhibited by the addition of calcium chloride.

True and Bartlett [3] have shown that calcium salts are absorbed

* Amplified form of a paper presented before the Second Pan-American Scientific Congress, Washington, January 4, 1916, and published by permission of the Secretary of Agriculture.

[1] *Jour. of Physiol.*, 3, 380 (1880–82); 4, 29 (1883–84); 5, 247 (1884–85).

[2] *Journ. Biol. Chem.*, 1, 366 (1905–06).

[3] True, R. H., and Bartlett, H. H., U. S. Dept. of Agric., Bureau of Plant Industry, Bull. 231, 1912; *Amer. Journ. Bot.*, 2, 255 (1915); 2, 311 (1915). See also True, Rodney H., *Amer. Journ. Bot.*, 1, 255 (1914).

by plants (*Lupinus albus*) at a greater range of concentrations than magnesium salts, and that the calcium salts apparently enable the plants to retain possession of the salts already present, and, further, that there is a certain ratio of magnesium to calcium which favors maximum absorption, while Loew[4] has demonstrated that the toxic action of magnesium salts on plants can completely be paralyzed by calcium salts. The antagonism which has been shown to exist between calcium and magnesium (and other electrolytes) in plants holds also true for the animal organism, as was experimentally demonstrated by Meltzer and Auer,[5] Loeb,[6] and others. Inasmuch as in experiments of the above indicated nature the experimenter is frequently confronted with the necessity of estimating calcium and magnesium in whole series of culture solutions before and after the plants have grown in them for a certain length of time, or in various plant and animal materials, or in feeding stuffs offered animals as well as in their organs and tissues, a speedy and at the same time accurate method for the determination of calcium and magnesium seems to be indispensable. While the present methods for their quantitative determinations are accurate, they have the disadvantage of requiring too much time. In this paper it will be shown that the pulp filter, which was shown by the writers[7] to be superior to either filter paper or asbestos for the filtration of the ammonium phosphomolybdate precipitate, can successfully be applied to the filtration of calcium oxalate and magnesium ammonium phosphate as well.

EXPERIMENTAL.

Preparation of Chestnut Bark for Analysis.

Having occasion to determine calcium and magnesium in a number of chestnut-bark samples, healthy and infected, we have decided to apply the pulp filter to the estimation of these elements. Bark removed from various chestnut trees was cut to small slices, dried, ground, and finally passed through a 30-mesh sieve. The bark powder obtained was burned in an electric muffle oven where the heat was gradually increased to a dull red heat until the

[4] *Landwirtsch. Jahrb.*, 46, 733 (1914); *Biochem. Zeitschr.*, 38, 236 (1912).

[5] *Centralb. f. Physiol.*, 21, 788 (1907); *Biochem. Zeitschr.*, 38, 238 (1912).

[6] *Biochem. Zeitschr.*, 32, 308 (1911).

[7] Jodidi and Kellogg, *Biochem. Bulletin*, vol. 4, 1915.

residues represented a uniform gray ash, which was used for analysis.

Two grammes of bark ash were carefully dissolved in dilute hydrochloric acid and evaporated to dryness, the treatment with acid and evaporation being repeated three times. The final dust-dry residue was treated with hydrochloric acid, filtered and thoroughly washed with hot water. Filtrate and washings from the insoluble residue—which consisted of silica, sand, and carbon—were cooled and made up to 500 c.c. Of this solution (S) several portions of 50 c.c. each were treated as follows: On being neutralized with ammonia, the solution was slightly acidified with acetic acid, when 0.5 c.c. of ferric chloride and 5 to 6 c.c. of concentrated ammonium acetate solution were added and the whole heated to boiling. The brown precipitate (basic ferric, aluminic—phosphate and acetate) was rapidly filtered off and washed with a boiling hot very dilute solution of ammonium acetate, filtrate and washings being used for calcium estimation.

Gravimetric Estimation of Calcium.

The ordinary [8] method of calcium determination involves, as is known, repeated decantation, filtration, and washing of the calcium oxalate precipitate, which, if magnesium is present (as was the case with the chestnut-bark ash), has to be redissolved and reprecipitated, which necessitates a repetition of all mentioned operations. The final calcium oxalate obtained is on drying to be separated from the filter, in order to be burned separately, etc. The employment of the paper pulp filter, which completely retains the calcium oxalate precipitate despite rapid filtration, permits of doing away with most of the above operations, which require considerable time, labor, and attention. The method adopted for the work with the pulp filter was as follows:

A Gooch crucible is placed in a somewhat larger platinum [9] crucible with cover and both are heated, cooled, and weighed together. The Gooch crucible is now placed in the funnel of a suction flask, provided with a pulp filter, whereupon the calcium [10]

[8] Fresenius, "Quantitative Chemical Analysis," vol. i, pp. 235–6 (1903).

[9] The platinum crucible is used to prevent loss, which could occur if the pulp filter with the calcium oxalate would be heated directly in the Gooch crucible.

[10] The precipitation of calcium took place always in 50 c.c. of solution (S), equal to 0.2 gramme of bark ash.

oxalate obtained, as usual, with ammonium oxalate in slightly ammoniacal solution is (on standing for twelve hours), *together with the supernatant liquid, at once* filtered [11] off into the crucible. The beaker, in which traces of calcium oxalate may remain, is now rinsed out several times with boiling hot water, which is also used for washing the precipitate in the Gooch. The operation of filtering off the precipitate and washing it free from foreign matter goes very rapidly, taking altogether about five minutes. Because of the presence of not insignificant proportions of magnesium in the chestnut-bark ash, the precipitate in the Gooch crucible is now redissolved by means of hot dilute hydrochloric acid—which can be added by stirring up the precipitate with a stream from the nozzle of a wash bottle—and thoroughly washed with hot water. Solution and washings are allowed to run into the precipitation beaker, where the redissolved calcium oxalate is heated to boiling and, with addition of a few cubic centimetres of ammonium oxalate and of ammonia in some excess, reprecipitated. On standing on the steam bath for about thirty minutes the precipitate, on being stirred up with the supernatant liquid, is filtered off quantitatively on the same pulp filter and thoroughly washed with hot water. The Gooch is now placed in the platinum crucible (with which it was weighed) and the precipitate with the pulp filter is directly [12] heated over the Bunsen burner, the small flame of which is at first cautiously directed towards the fore-part of the inclined crucible, where there is no substance, in order to remove the moisture. When the flame is gradually increased and moved backwards it causes the pulp filter first to carbonize, and, when it begins to burn, it is very readily burned to ash, sometimes with sparkling, throughout the whole mass, due to the more or less finely divided state of the paper fibre of which the pulp filter is made up. By finally burning the substance in the covered crucible over the blast [13] burner, as usual, it is finally converted to calcium oxide. The results are presented in Table I.

[11] The filtrate is, as a rule, faultlessly clear, and does not need any refiltration.

[12] The precipitate with the filter may, of course, be warmed in the oven until nearly dry before they are burned; the drying, however, is not necessary for obtaining good results.

[13] Or Meker's burner.

TABLE I.

Chestnut-bark ash. No.	Analysis No.	CaO found		Remarks
		Gramme	Per cent.	
1	* 1[14]	0.0947	47.35	This was healthy bark taken from a chestnut tree about 14 years old, with a periphery of 15½ inches. Only the top of the chestnut was still living.
	* 2	0.0947	47.35	
	3	0.0949	47.45	
2	* 4	0.0840	42.00	The infected bark of No. 2 was taken from the same chestnut (see No. 1). The canker was one year old.
	5	0.0839	41.95	
3	* 6	0.0868	43.40	This was healthy bark taken from a chestnut tree 22 years old. Only the upper branches of the tree were covered with leaves.
	* 7	0.0870	43.50	
	8	0.0876	43.80	
4	* 9[15]	0.0867	43.35	The infected bark of No. 4 was taken from the same tree as in No. 3. The canker was one or two years old.
5	*10	0.1005	50.25	No. 5 was made up of barks taken from several infected trees. The cankers were from one to three years old.
	11	0.1016	50.80	

While the question of any relationship between the fungus metabolism, on the one hand, and the percentage of the inorganic constituents in the barks, on the other, needs considerably more data and will be discussed in another paper, it may be mentioned here that the corresponding healthy and infected chestnut-bark samples were taken from the same trees in order to exclude the influence of age, since the percentage of calcium in bark usually increases with age, just as the proportion of magnesium decreases. A glance at Table I shows that the analyses Nos. 1 and 2, the precipitates of which were filtered through pulp, agree well with each other, just as they agree with the check analysis No. 3, the precipitate of which was filtered through standard quantitative filter paper. This is also true of all the other analyses, despite the fact that the filtration [16] and washing on the pulp filter takes only

[14] In the analyses designated with a * the calcium oxalate precipitate was filtered on a pulp filter, while in the rest of the analyses, which represent the controls, the precipitate was filtered on quantitative filter paper (S. & S. No. 590).

[15] The check analysis corresponding to No. 9 was lost.

[16] Decantation is here unnecessary.

some five minutes, instead of from 30 to 35 minutes required for the paper filter.

Since, in the presence of magnesium, calcium oxalate has to be redissolved and reprecipitated, as was the case with the chestnut-bark ash, it means that the application of the pulp filter to the calcium determination enables one to save in this case about one hour's time for each analysis, which is especially important when series of analyses are to be made.

When in analytical (or synthetical) work the precipitate only is desired, the substance may be filtered through the pulp filter into an ordinary suction flask. If, however, both precipitate and filtrate are necessary, it is best to catch the filtrate directly in the vessel—beaker, dish, or flask—in which it is intended to subject the filtrate to further treatment, thus doing away with the necessity of transferring the filtrate from the suction flask to the desired vessel, which involves loss of time and labor as well as dilution of the substance. For the purpose indicated, we are employing to our full satisfaction Witt's [17] filtering apparatus. Instead, however, of a ground-in funnel, we are using the Gooch crucible placed in a filter funnel which fits in a one-hole rubber stopper. The stem of the funnel is bent so as to touch the wall of the receiving beaker (or flask), thus avoiding loss of substance through spattering. A crystallizing dish may conveniently be used as support for dishes or small beakers (see Fig. 1). For catching filtrates in large flasks or dishes we are using the bell-jar filtering apparatus with the arrangement employed in Witt's apparatus.

Volumetric Estimation of Calcium.

In the determination of calcium by titrating the oxalic acid combined with it with standard potassium permanganate solution, it is recommended in the literature [18] that, prior to the titration, the calcium oxalate precipitate be quantitatively separated from the filter paper. This, of course, requires additional work. Our ob-

[17] A new analytical suction filter which does not seem yet to be on the market and is in the main a modification of Witt's filtering apparatus is described in *Journal of the American Chemical Society*, 37, 1519 (June, 1915).

[18] Abderhalden, "Handbuch der biochem. Arbeitsmethoden," vol. i, p. 407 (1910). Hoppe-Seyler's "Handbuch der Physiol. und Pathol. Chem. Analyse," p. 545 (1909). C. Neuberg, "Der Harn," vol. i, p. 169 (1911). Treadwell, "Analytical Chemistry," First Edition, vol. ii, p. 491.

servations go to show that the pulp filter in no way interferes with the accuracy of the titration. We proceed as follows: The calcium oxalate precipitate, filtered and washed on the pulp filter, as outlined in the gravimetric estimation of calcium, is by means of a glass rod transferred to the precipitation beaker, *together* with the pulp filter. To remove traces of calcium oxalate from the Gooch crucible, the latter is placed in a glass funnel under which the precipitation beaker stands. Now hot dilute sulphuric acid

FIG. 1.

(some 350 c.c. of water + 10 c.c. of concentrated H_2SO_4) is poured on the Gooch, whereupon the beaker content is stirred for a few seconds with a glass rod which reduces the pulp filter cake to pulp and dissolves the calcium oxalate completely. On heating to about 70 to 80° C., the oxalic acid is titrated with standard potassium permanganate solution, usually tenth-normal. The volumetric estimation of calcium as outlined can be accomplished in very much less time than by the ordinary method. Thus, five consecutive volumetric calcium estimations to which the pulp filter (prepared from S. & S. paper filters, No. 589) was applied

required one hour, which means twelve[19] minutes per analysis. Yet the analyses in all of which equal volumes of the same calcium chloride solution were employed closely agreed with each other, the figures in question being, respectively, 14.75, 14.73, 14.78, 14.77, 14.70 c.c. of n/10$KMnO_4$. In order to have an impartial judgment as to whether or not the pulp filter gives as accurate results as standard quantitative filter paper, it was deemed advisable to run a number of parallel analyses, which are reported in Table II.

Table II.

Chestnut-bark ash No.	Analysis No.	Standard $KMnO_4$ used, c.c.	CaO found		Average	Remarks
			Gramme	Per cent.		
1	* 1[20]	33.25	0.0936	46.80	46.85	Check analysis corresponding to analyses Nos. 1 and 2 was lost. 1 c.c. $KMnO_4$ = 0.002814714 gr. CaO.
	* 2	33.33	0.0938	46.90		
2	* 3	29.60	0.0830	41.50	41.50	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	* 4	29.60	0.0830	41.50		
	5	29.39	0.0824	41.20		
	6	29.50	0.0827	41.35	41.40	
	7	29.70	0.0833	41.65		
3	* 8	30.63	0.0859	42.95	43.08	
	* 9	30.80	0.0864	43.20		
	10	30.70	0.0861	43.05	43.05	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	11	30.70	0.0861	43.05		
4	*12	30.42	0.0853	42.65		
	*13	30.50	0.0855	42.75	42.72	
	*14	30.50	0.0855	42.75		1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	15	30.19	0.0847	42.35		
	16	30.42	0.0853	42.65	42.42	
	17	30.12	0.0845	42.25		
5	*18	35.68	0.1001	50.05		
	*19	35.52	0.0996	49.80	49.97	
	*20	35.68	0.1001	50.05		1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	21	35.60	0.0998	49.90		
	22	35.79	0.1004	50.20	49.97	
	23	35.50	0.0996	49.80		

An examination of Table II reveals the fact that the analyses whose calcium oxalate precipitates were filtered through pulp

[19] From the beginning of the filtration of the calcium oxalate to the end of the titration.

[20] The * in front of the numbers designates that the *pulp* filter was applied to the analyses in question, while in the rest of the analyses filter paper (S. & S., No. 590) was employed for the filtration of the calcium oxalate precipitate.

show concordant results, agreeing at the same time with the check analyses whose precipitates were filtered on good quantitative filter paper (No. 590, S. & S.). This is true, *e.g.*, of analyses Nos. 3 and 4, on the one hand, and 5, 6, 7, on the other, or of 18, 19, 20, on the one side, and 21, 22, 23, on the other.

The question naturally arises as to whether or not the methods described for estimation of calcium in chestnut-bark ash have general applicability. To answer this question the following experiments were performed.

Twenty grammes of calcium chloride ($CaCl_2$, 2aq.) were dissolved in water and made up to four litres. In six portions of this solution the calcium was precipitated as oxalate in the ordinary way, with the results recorded in Table III.

TABLE III.

No. of analysis	Of solution used, c.c.	CaO found, gramme	Remarks
1	50	0.0859	The calcium oxalate precipitates were left in the beakers over night and were filtered next morning on S. & S. paper filters, No. 590.
2	50	0.0855	
3	25	0.0422	
4	25	0.0423	
5	25	0.0425	
6	25	0.0423	
Average in 25 c.c.		0.0425	

In ten other portions of the above solution the calcium precipitated in the form of oxalate was filtered on standing on the steam bath for from 15 to 30 minutes. The results obtained are expressed in the following table:

TABLE IV.

No. of analysis	Of solution used, c.c.	CaO found, gramme	Remarks
1	25	0.0422	In Nos. 1, 2, 7, 8, 9, and 10 the calcium oxalate precipitates obtained in the ordinary way were allowed to stand on the steam bath for half an hour prior to their filtration, while in Nos. 3, 4, 5, and 6 the precipitates were filtered on standing on the steam bath for but 15 minutes.
2	25	0.0425	
3	25	0.0427	
4	25	0.0424	
Average		0.0424	
5	25	0.0424	
6	25	0.0424	
7	25	0.0421	
8	25	0.0424	
9	25	0.0426	
10	25	0.0423	
Average		0.0424	

From the data presented in Tables III and IV it is evident that from pure calcium chloride solution the calcium could be precipitated quantitatively within fifteen to thirty minutes. Since the analyses Nos. 1 to 4 whose calcium oxalate precipitates were filtered through good filter paper (S. & S. filters, No. 590) closely agree with the analyses 5 to 10 whose precipitates were filtered through paper pulp, it follows that the pulp quantitatively retained the calcium oxalate precipitates despite rapid filtration.

In six further portions of the above calcium chloride solution the calcium oxalates filtered and washed on pulp were titrated with standard potassium permanganate solution as outlined in this paper. The results in question are expressed in the table below.

Examination of Table V reveals the fact that the volumetric analyses show concordant results which stand in good agreement with the corresponding gravimetric analyses recorded in Table IV.

Table V.

No. of analysis	Of solution used, c.c.	Standard $KMnO_4$ used, c.c.	Corresponding CaO, gramme	Remarks
1	25	15.03	0.0423	1 c.c. $KMnO_4$ = 0.002814714 gr CaO.
2	25	15.03	0.0423	
3	25	15.01	0.0422	
4	25	15.04	0.0423	
5	25	15.05	0.0424	
6	25	15.04	0.0423	
Average			0.0423	

Thus the data obtained with calcium chloride solution fully confirm the results secured with chestnut-bark ash. In other words, the paper pulp is generally applicable to the quantitative estimation of calcium, no matter whether it is to be determined in inorganic compounds or in biological materials.

In all of the calcium estimations reported in this paper (see Tables I to V) the filtrates from calcium oxalate filtered on paper pulp were, as a rule, at once perfectly clear, in spite of the fact that the quantitative filtration and complete washing of each individual calcium oxalate precipitate required but five or six minutes. In one or two cases, however, the calcium oxalate passed through the pulp filter and refiltrations were necessary. It seemed desirable more definitely to ascertain the conditions under which the calcium oxalate precipitate passes through the pulp filter, or is

completely retained by it. With this object in view ten grammes of calcium chloride were on solution in water made up to two litres. Various portions of this solution were uniformly made up with water to a total volume of 200 c.c., heated to boiling when the calcium was precipitated with boiling-hot ammonium oxalate solution, and the whole made slightly ammoniacal. On standing on the water-bath for about an hour, the precipitate was stirred up and together with the liquid filtered on a pulp filter, washed with hot water, and titrated with standard potassium permanganate solution. The results are summarized in Table VI.

TABLE VI.

No. of analysis	Of solution used, c.c.	Filtration (only) required, minutes	$KMnO_4$ used, (1 c.c. = 0.0028595 gr. CaO), c.c.	Corresponding CaO, gramme	Remarks
1........	10	0.7	5.75	0.0164	Filtrate (from calcium oxalate) perfectly clear.
2........	10	0.6	5.71	0.0163	Filtrate perfectly clear.
3........	25	0.6	14.50	0.0415	Filtrate perfectly clear.
4........	25	1.0	14.53	0.0415	Filtrate perfectly clear.
5........	50	2.0	29.20	0.0835	Filtrate perfectly clear.
6........	50	2.0	29.20	0.0835	Filtrate perfectly clear.
7........	100	14.0	58.30	0.1667	Filtrate not quite clear. One refiltration gave clear filtrate.
8........	100	....	.....	......	Very cloudy. Refiltration unsuccessful.
9........	200	....	.....	......	Filtrate very cloudy. Three refiltrations did not give clear filtrate.

From the data given in the table it would appear that the concentration of the liquid in which calcium is precipitated as oxalate plays a considerable rôle. In other words, *cæteris paribus,* the calcium oxalate precipitates formed in dilute solutions seem to consist of better, larger crystals which filter well through pulp and give at once perfectly clear filtrates. Thus the filtration (and washing) of calcium oxalate on a pulp filter requires the less time, the smaller is the amount of calcium used. The filtrate from calcium oxalate was perfectly clear so long as the amount of calcium oxide ranged from about 0.01 gramme CaO (or less) to 0.10 gramme CaO. When amounts larger than 0.10 gramme CaO

(= 0.23 gramme calcium oxalate) are analyzed, the filtrate from calcium oxalate is cloudy, provided the precipitation of calcium oxalate takes place in a volume of but 200 c.c. of liquid.

From the above it would follow that in analyzing larger amounts of calcium it is necessary to precipitate it as oxalate in larger volumes in order to get at once clear filtrates, which was actually confirmed by experiments. At any rate, in the application of the pulp filter to the analysis of calcium it is, for the reasons stated, advantageous to use small amounts of substance. In this connection it seems reasonable to assume that the difficulties encountered in the filtration of calcium oxalate precipitates, which not infrequently pass * through paper filters and necessitate repeated refiltration, may in part be due to the fact that the precipitation of calcium as oxalate is performed in not dilute enough solutions.

Gravimetric Estimation of Magnesium.

As in the case of calcium, the application of the pulp filter enables one to eliminate tedious operations incidental to the ordinary method of magnesium estimation, such as repeated decantation, filtration, and washing of the magnesium ammonium phosphate precipitate, as well as its drying and separation from the filter before its ashing. The way we proceeded was as follows: The filtrates and washings from the calcium oxalate precipitates (corresponding to 0.2 gramme of chestnut-bark ash) were evaporated on the steam bath to dryness, freed from ammonium salts by gentle ignition, whereupon the residues were treated with dilute hydrochloric acid, filtered and washed quantitatively. In the combined filtrate and washings the magnesium was precipitated, as usual, in the form of $MgNH_4PO_4$, which, on standing for twelve hours, was, *together with the supernatant liquid*, at once filtered and washed with 2½ per cent. ammonia on a pulp filter.[21] The quantitative filtration and washing of the magnesium

* Abderhalden, Handbuch Biochem. Arbeitsmeth., vol. i, p. 406 (1910); Treadwell, Analyt. Chemistry, vol. ii, p. 66 (1907); Fresenius, Quant. Anal., vol. i, p. 235 (1903); Hoppe-Seyler's Handbuch Physiol. and Pathol. Chem. Anal., 8th Edition, p. 545 (1909).

[21] If not otherwise stated, the arrangements for the platinum and Gooch crucibles, for the filtration of the magnesium ammonium phosphate precipitate, and so on, were made exactly as described in the estimation of calcium.

ammonium phosphate on the pulp filter takes only from three to six minutes, as against about a half-hour required for the paper filter. The Gooch placed in the platinum crucible (with which it was weighed) is now heated directly[22] over the burner, at first very cautiously, gradually increasing the flame, and finally igniting the covered crucible over the blast burner until the substance is converted to magnesium pyrophosphate.

In spite of the rapid filtration of the magnesium phosphate precipitate, the results which are expressed in Table VII show that

TABLE VII.

Chestnut-bark ash No.	Analysis No.	$Mg_2P_2O_7$ found Gramme	Corresponding MgO		Average
			Gramme	Per cent.	
1	* 1[23]	0.0627	0.02272	11.36	11.42
	* 2	0.0633	0.02294	11.47	
	3	0.0630	0.02283	11.42	11.42
2	* 4	0.0505	0.01833	9.16	8.96
	* 5	0.0483	0.01749	8.75	
	6	0.0498	0.01804	9.02	9.02
3	* 7	0.0785	0.02845	14.23	14.38
	* 8	0.0801	0.02903	14.52	
	9	0.0744	0.02805	14.03	14.12
	10	0.0781	0.02831	14.16	
	11	0.0781	0.02831	14.16	
4	*12	0.0638	0.02311	11.56	11.66
	*13	0.0631	0.02285	11.43	
	*14	0.0652	0.02361	11.81	
	*15	0.0653	0.02365	11.82	
	16	0.0650	0.02354	11.77	11.77
5	*17	0.0339	0.01228	6.14	6.12
	*18	0.0337	0.01221	6.11	
	19	0.0320	0.01159	5.80	5.80

the precipitate is quantitatively retained by the pulp filter, since the magnesium estimations whose precipitates were filtered on pulp agree very well with the check analyses whose precipitates were filtered on standard quantitative filter paper.

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[22] Drying the pulp filter with the precipitate prior to ashing is here not essential for obtaining accurate results, as direct experiments have convinced us.

[23] As in Tables I and II, the * in front of the numbers designates that the *pulp* filter was applied to the analyses in question.

It seemed desirable to ascertain the percentage of saving with various kinds of filter paper when used as pulp. Hence, three S. & S. filters, No. 595, of 11 cm. diameter, were reduced with water to pulp which yielded in Gooch crucibles twelve pulp filters. Five consecutive volumetric calcium estimations whose calcium oxalate precipitates were filtered through these pulp filters required for the same amount of calcium solution 29.71, 29.70, 29.70, 29.70, 29.72 c.c. n/10 $KMnO_4$ respectively. Equally, three S. & S. filters, No. 589, of 12½ cm. diameter, were reduced to pulp which was sufficient for making fourteen pulp filters. Quantitative analyses whose precipitates were filtered through the pulp filters gave accurate results.

In like manner three filters of 9 cm. diameter which were cut from S. & S. sheet filter paper, No. 598, when reduced with water to pulp yielded twelve pulp filters. Three consecutive phosphoric acid estimations, in all of which equal volumes of the same phosphate solution were used, required for neutralization of the yellow precipitates (filtered through the pulp filters) 10.95, 10.81 and 11.00 c.c. n/2 NaOH respectively. Two further estimations in which the yellow precipitates were filtered through pulp filters prepared from S. & S. filters, No. 588—which from our previous work were known completely to retain the ammonium phosphomolybdate precipitate—required for neutralization of the yellow precipitates 10.95 and 10.95 c.c. n/2 NaOH respectively. Finally, three filters of 11 cm. diameter which were cut from commonest sheet filter paper (used for technical work) were reduced with 150 c.c. water to pulp, to which now 150 c.c. of 20 per cent. hydrochloric acid were added and the whole left over night. Next morning the pulp mass was sucked off on a "nutsche" and washed with hot water. The washed pulp was shaken with water (450 c.c.) to an emulsion which yielded on Gooch crucibles seventeen pulp filters. This experiment was repeated with the same result. Three consecutive phosphoric acid estimations in which the yellow precipitates were filtered through the pulp filters required for neutralization of the yellow precipitates (obtained from equal volumes of the phosphate solution) 11.05, 10.91, 10.90 c.c. n/2 NaOH respectively. As check three other estimations were made whose yellow precipitates were filterd through pulp prepared from S. & S. filters, No. 588. They gave respectively 10.89, 10.91, 10.99 c.c. n/2 NaOH.

The above analyses show that the pulp filters prepared from various kinds of filter paper quantitatively retain the precipitates in question. For the sake of convenience the data are expressed in Table VIII.

It is hardly necessary here to mention that the larger and thicker the paper filters are, the more pulp filters they yield on

TABLE VIII.

Kind of paper filters used	Diameter of paper filters, cm.	Paper filters used, number	When reduced with water to pulp they yielded pulp filters (Gooch) number	Economy of filter paper, per cent.
S. & S., No. 595	11	3	12	300
S. & S., No. 589	12½	3	14	367
S. & S., No. 598	9	3	12	300
Commonest sheet filter paper	11	3	17	467

reduction with water, and *vice versa*. The paper filters used in the experiments of Table VIII were of the sizes which are frequently employed in quantitative analysis.

CONCLUSIONS.

1. The application of the pulp filter to the filtration of the calcium oxalate precipitate enables one to eliminate the tedious operations of repeated decantations, filtrations, washings, etc., and to save half an hour for calcium estimation. In case, however, the calcium oxalate precipitate has to be redissolved and reprecipitated, as is, *e.g.*, necessary in the presence of a considerable percentage of magnesium, the saving of time is about one hour for each individual analysis.

2. It is possible, by the application of the pulp filter, to make a volumetric calcium estimation in about twelve [24] minutes, which is about one-third or one-quarter the time necessary for an analysis when filter paper is used for the filtration of the calcium oxalate precipitate.

3. By employing pulp filter for the filtration of the magnesium

[24] Counting the time from the beginning of the filtration of the calcium oxalate precipitate to the end of the titration.

ammonium phosphate precipitate one is able to do away with the tedious operations incidental to the work with filter paper and to gain about a half-hour's time for each analysis.

4. The work with the pulp filter gives as accurate results for calcium and magnesium as the work with standard filter paper.

5. By using for filtration pulp [25] instead of paper, one is able to economize from 300 to 467 per cent. of filter paper.

Washington, D. C., December, 1915.

[25] The pulp was obtained from S. & S. filters, No. 589 (see p. 15).

Process for Producing Colored Photographic Prints. Anon. (*Scientific American,* vol. cxiii, No. 24, December 11, 1915.)—A new adaptation of the three-color process of photography in the colors of Nature, the product of the efforts of the well-known worker in this field, Frederick E. Ives, makes possible the production of photographic prints in colors.

The principle of employing three plates screened by filters of red, yellow, and blue is retained. The manner in which the new camera exposes the three plates to the light from the lens is highly ingenious. The three sensitive plates are arranged for commercial use in a metal carrier similar to the ordinary film pack. The carrier is hinged at the bottom, and when placed in the camera and the slide withdrawn the front of the carrier faces to the bottom of the camera, carrying with it the front one of the three plates, two of the plates remaining upright in the back of the camera with their sensitive surfaces together. An amber-tinted glass held at 45 degrees with the horizontal and vertical plates reflects a portion of the rays from the lens upon the bottom plate and serves as a color filter to the rays passing through it to the plates in the rear. The last-mentioned rays strike the first of the two plates without hindrance, but before reaching the second they are further filtered by the coating of the forward plate. Thus each plate is suitably screened at the time of exposure and all are exposed at the same time. By a mechanical arrangement the amber-colored filter is moved aside and the bottom plate brought back into its original position in the holder.

The negatives are printed, one upon paper that makes a print in blue tones, the other two upon transparent bichromated film. The latter, after staining with dyes corresponding to the color of the screens through which their respective negatives were made, are then superposed over the blue print with the outlines in register, whereupon the subject is faithfully reproduced in all its colors. It is stated that the sheen of the satin dress, the soft and colorful shadows of filmy drapery, and the cobwebby bloom of the grape are all recorded faithfully by the camera and imparted to the prints.

THE PHYSICAL PHOTOMETER IN THEORY AND PRACTICE.*

(Additional Note)

BY

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In a recent issue of this Journal the writer published[1] new quantitative data on the infra-red transmission of solutions containing cupric chloride, potassium dichromate, etc. The solution, which had been made up to give a transmission curve coinciding with the visibility of radiation curve of the average eye (when stimulated with light of a given intensity), was found to transmit a small amount of infra-red radiation, and the problem was to find the minimum thickness of a layer of clear water which would absorb substantially all the infra-red rays. The measurements in different parts of the spectrum dealt with quantities of radiation varying from 1 part in 30,000 to 1 part in 500 of the total radiation at a particular wave-length. That is to say, quantities of energy were measured with considerable precision which under ordinary conditions could not have been detected, or, if detected, would be considered negligible. However, for one particular application, viz., in a physical photometer, the quantities involved are not negligible, and one object of the paper was to present to the public for the third[2] and, what is hoped to be the last, time (for the writer) the conditions that must be fulfilled in order to absorb all the infra-red rays by means of this type of transmission screen.

After having worked out the details for eliminating the infra-red rays, evidently the logical thing to do was to place the luminosity solution and water cell in front of a thermopile and determine the performance of the combination as a physical photometer.

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* Communicated by the Author.

[1] This Journal, September, 1915, p. 335.

[2] In two previous papers quantitative data were given: *Bull. Bureau of Standards*, 7, p. 655, 1911; 9, p. 110, 1912.

If certain difficulties can be overcome it is probable that, for certain kinds of investigations, the physical photometer will supersede the present method of photometry with its cumbersome and expensive equipment. Naturally there are prejudices to be overcome; and if an appeal is to be made to the illuminating engineer to try a new method of photometry, evidently all the available data (which at present are meagre) bearing upon the performance of the device should be presented. The second and principal reason for publishing the data was to show the performance of a physical photometer as found by one who had unexpectedly and reluctantly inquired into the merits of an instrument in which he had, up to that time, but little faith. The performance is admittedly favorable.

In presenting the data no attempt was made to properly accredit to the numerous predecessors the contributions made by each one; for the general discussion of the subject of physical photometry had already been ably presented by Dr. H. E. Ives,[3] whose contributions to the subject are well known and who is a strong advocate of this method of photometry.

In view of the difficulties which the writer has experienced in convincing others as to the performance of this device, in Table I are given data which were omitted in order to shorten the preceding paper. In that paper mention was made of these data which relate to the Ives luminosity solution diluted to one-fifth and used in a 5-cm. cell. No particular importance (other than the precision attained under various conditions, thus emphasizing the constancy of the behavior of the physical photometer as compared with the eye) is to be attached to these data, in view of the fact that the solution is not entirely opaque to infra-red radiation. However, it is sufficiently opaque to the infra-red so that the addition of an extra cell of water 1 cm. in thickness (see Table I, "Water Cell") has no appreciable effect upon the observations. This method of elimination, by adding absorption cells of water, does not, however, decide whether all the infra-red is eliminated. Only by a spectro-radiometric examination can this question be definitely determined. By a peculiar circumstance, the dilution of the luminosity solution seems to have changed the shape of its spectral transmission curve, so that when using it in determining

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[3] Ives, *Trans. Illum. Eng. Soc.*, 10, p. 101, 1915.

the ratio of transmissions of certain blue and yellow solutions the value is B : Y = 1.001, which was the value sought by Ives and Kingsbury.

TABLE I.

Transmission of a yellow solution determined with a physical photometer having the luminosity solution diluted to 1/5 its concentration, contained in a 5-cm. cell. Tests were made with and without an additional cell of water 1 cm. in thickness placed in front of the thermopile.

Transmission: July 30, 1915. Surface thermopile, No. 56.

0.628 no water cell; temperature 29.2°.
0.623 no water cell.
0.624 with water cell.
0.625 no water cell.
0.628 no water cell.

M = 0.625

0.622 When using a 1-cm. cell of luminosity solution and correcting for 13.6 per cent. infra-red transmitted by the luminosity solution.

Ratio of transmission: Blue ÷ yellow solutions. July 30, 1915.

Using an additional 1 cm. cell of water	No water cell
0.997	1.000
1.000	1.000
1.003	1.000
0.994	
1.011	M = 1.000
1.006	
1.003	
M = 1.002	
1.004 July 29, using a linear thermopile.	
0.999 July 28, using a linear thermopile; light is non-uniform.	
Mean 1.002 at 29° C.	

The inconsistency in the writer's previous paper in which a ratio of B : Y = 1.083 was obtained with a physical photometer is now explained. From the recent paper by Ives[4] it appears (1) that the original scheme of setting the transmissions of certain blue and the yellow solutions to equality, first with a physical photometer[5] and then testing them with a flicker photometer, was abandoned, and (2) that the blue and the yellow solutions, which gave equality of transmission by the flicker photometer, gave equal-

[4] Ives, this JOURNAL, October, 1915, p. 117. Ives and Kingsbury, *Phys. Rev.*, 7, p. 319, 1915.

[5] Ives and Kingsbury, *Trans. I. E. S.*, 10, p. 207, 1915.

ity of transmission with the physical photometer only after making up a new luminosity solution, having a transmission curve which is slightly shifted with respect to the luminosity curve of the average eye. In other words, the blue and the yellow solutions were first set to equality of transmission photometrically with a flicker photometer instead of radiometrically, as mentioned in the previous paper.

The transmission curve of the solution is obtained with a spectrophotometer by comparing lights of the same color. The luminosity curve of the eye is obtained with a flicker photometer by comparing the differently-colored lights with white light; and the question is: Does the luminosity curve of the eye, as determined with the equality-of-brightness photometer, really coincide with the one obtained with the flicker method, or is it shifted toward the red (for high intensities), as suspected?

While some of the data harmonize, others are discordant. The visibility of radiation curves themselves can hardly be called satisfactory from a radiometric point of view. One set of curves is based upon an energy evaluation in which the spectral energy curve is computed upon the basis that the source (which was a carbon incandescent lamp) is at a certain temperature. The light is passed through the spectrometer and corrections are made for the loss of light in the apparatus. The weak point in this method of investigation is the uncertainty of the temperature and, hence, the energy distribution of the source.

Some years ago an investigation was made, in this Bureau, of the spectral energy curve of an acetylene flame, set flat-wise and also edge-wise to the slit of (1) a mirror spectro-radiometer and (2) a spectro-radiometer with achromatic lenses having excellent optical corrections. From this it appears that one can use a spectro-radiometer having lenses to obtain luminosity curves by using a source having a known spectral energy curve and making corrections for losses in the apparatus. It will therefore be a simple matter for this Bureau to issue standard light sources having a certified spectral energy distribution, which can be used by experimenters throughout the country. In this way it will be possible to easily obtain visibility of radiation curves of a large number of observers and reduce the data to one common standard. In view of the great divergence in the observations, made by different observers, this method of energy evaluation seems to be

sufficiently refined for this particular investigation. However, after several years' deliberation upon this subject, it does not appear to be the proper method of procedure for investigations in general.

Obviously the logical procedure is to reduce stray light by using absorption screens, to use spectral lines whenever practicable, and to measure the stimulus at the observing slit. In view of the high sensitivity required to measure, radiometrically, the light stimulus of a 2-degree photometric field (recommended by Ives for the photometric comparisons), it will be better to observe the spectral energy curve by using the whole length of the slit and the full aperture of the lenses. For good lenses this same energy distribution will hold for a 2-mm. slit and a small aperture. The remaining measurements are also relative and may be made by reducing the intensities either by varying the slit opening, or by using crossed nicol prisms between the slit and the source. The second set of visibility-of-radiation curves now available was obtained by the method of measuring the energy at the observing slit. However, difficulties were experienced from unsteadiness in the radiometric apparatus, so that, while we have this much data [6] to be thankful for, more work must be done. In view of the fact that all the visibility of radiation observations by various observers are included in these two sets of energy evaluations, it is not surprising to find that the new, arbitrarily-made luminosity curve solution fits other experimental data better than the old solution described by Ives.

In addition to these perplexities, the psychologist aptly questions the propriety of using the flicker method as compared with the equality-of-brightness method of photometry, claiming that the two methods must give different values,[7] in view of the fact that the sensations aroused by lights differing in color value rise to their maximum brightness at different rates when using the flicker method. Has the physicist answered this question satisfactorily? The psychologist admits, of course, that in the flicker method the range in the settings is smaller than in the equality-of-brightness

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[6] Nutting, *Trans. I. E. S.*, **9**, p. 633, 1914. In view of this fact it is relevant to add that this investigation and the mechanical equivalent of light were authorized four years ago and satisfactory progress has been made radiometrically. The main reason why the writer has held aloof from this problem for the past two years is because he has not been able to reconcile certain psychological facts with physical procedure.

[7] Farree and Rand, *Psychol. Rev.*, **22**, p. 110, 1915.

settings; but he maintains that the mean values will be different, and that the equality-of-brightness method is the one that gives the true value.

Evidently much remains to be done, in spite of the extensive work of Ives and Kingsbury in the production of a luminosity curve solution which satisfies all of their tests, and hence satisfies the requirements of a physical photometer having as essential parts (1) a thermopile and (2) a solution whose transmission curve coincides with the luminosity curve of the average eye.

It is desirable to reproduce Table II, which was published in the previous paper, in order to make a minor correction to one value which was copied erroneously in making up the table and to discuss more thoroughly the precision attained. It is to be noticed that in the first column of this table there are variations amounting to several per cent. in some of the determinations. Hence the criticism can be made that the device is not a precision instrument. It is to be emphasized, however, that this large variation is not due to an inherent fault in the instrument, but in the operation of the lamp. Neglecting the two "Poor sets" for the reasons previously given, the other determinations would have been more regular if the change in current from 0.3108 to 0.3258 ampère had been

Table II.

Giving the Ratios of Luminous Intensities, as Determined with a Physical Photometer, for Different Currents.

Ampères		
.3258 / .3108	.3404 / .3258	.3542 / .3404
1.356 →	1.319	
	1.311	
←	1.311	
1.351		
1.344		
1.346 →	1.313	
	1.314	
	1.313 →	1.273
		1.280
		1.273
	←	1.274
1.363 } 1.332 }	Poor set.	
1.337		
Mean values		
1.347	1.313	1.275

made in two steps instead of one, or if the higher intensity had been reduced by means of a sectored disk. This large change in current produced too great a change in the radiation emitted to be properly evaluated by the auxiliary galvanometer which was then being used. Columns 2 and 3 are to be considered for precision measurements which have a range of about 0.4 per cent.

In the October issue of this JOURNAL, under the title "The Establishment of Photometry on a Physical Basis," by H. E. Ives, the following statements are made:

"The practical physical photometer described under Section 4 is clearly the same instrument as that described by W. W. Coblentz in the September issue of this JOURNAL. Every detail of this photometer was worked out by the writer and Mr. E. F. Kingsbury. It was exhibited and described to Dr. Coblentz on the occasion of his two visits to our laboratory during the past year. It has been shown as well to numerous other visitors, for several of whom incandescent lamps and colored glasses have been measured. The device was described before the American Physical Society at its New York meeting, October 31, 1914, and the complete description has been in the hands of its journal, *The Physical Review*, since April. Its use forms one of the recommendations made by the writer to the Illuminating Engineering Society (*Trans. I. E. S.*, No. 4, p. 315, June 10, 1915) which are now under study at the Bureau of Standards on behalf of that society. H. E. I."

These remarks seem to imply that the visitor to Dr. Ives's laboratory was shown a device that was entirely new in every detail, and that the writer is guilty of publishing a description of this apparatus without giving Dr. Ives due credit. It is therefore of interest to recall that Houstoun [8] described a physical photometer consisting of a Rubens thermopile in front of which was placed a 3-cm. cell of copper sulphate and a 1-cm. cell of potassium bichromate of such concentrations as to give a transmission curve which coincided well with the luminosity curve of the eye. At a distance of 33 cm. from the thermopile he placed a 32-candle-power lamp, which he photometered at various voltages and simultaneously observed the galvanometer deflections. He obtained very good results (considering the lack of sensitivity of his radiometer), from which he concluded that the device could be used to

[8] Houstoun, *Proc. Roy. Soc. Lond.*, A 85, p. 275, 1911.

define our unit of light and as a basis for comparing lights of different color.

Having this work in mind, the subject of physical photometry was not new to the writer in May, 1914, when he first began designing and constructing thermopiles to be used by Dr. Ives and himself in a joint investigation of the mechanical equivalent of light. The only new thing that the writer could have obtained from Dr. Ives's laboratory, not already suggested by Houstoun and others, was the constituents of the luminosity solution, and, as his recent paper shows, the constituents of this solution are constantly being modified. The luminosity solution used in the joint investigation of the mechanical equivalent would naturally be used in a physical photometer, and the writer's paper (this JOURNAL, September, 1915) quoted the references to this and other papers by Ives and his collaborators.

It is to be noticed that our arrangements of a physical photometer are by no means similar. The one employed by the writer had a 1-cm. cell of clear water in front of the thermopile to absorb the radiations from the luminosity solution (which becomes warmed), thus preventing a shift of the zero reading of the galvanometer. A cell of clear water 2.5 cm. in thickness was placed in front of the luminosity solution to absorb the deep infra-red radiations and thus reduce the heating of the luminosity solution.

The illuminating engineer wants facts concerning the performance of the physical photometer when applied to measuring the light from incandescent lamps. In spite of all that has been written upon the subject of physical photometry, if we except Houstoun's measurements, my paper (this JOURNAL, September, 1915) gives the first crucial data on the performance of a physical photometer (consisting of a sensitive, quick-acting thermopile having in front of it a luminosity curve solution) in a test on incandescent lamps. Among other tests my paper gave the results of a comparison of a physical photometer with a visual (equality-of-brightness) photometer in which the test object was a standard incandescent lamp which had been photometered by various observers in various laboratories situated throughout the country. The recent paper by Ives and Kingsbury,[9] which deals with the physical and visual (flicker) photometry of certain blue and yellow

[9] Ives and Kingsbury, *Phys. Rev.*, 6, p. 319, 1915.

solutions, strengthens the view held from the beginning, that my contribution to the subject of physical photometry is a distinct practical application which had not been obtained by others and hence could not detract credit from them. As for my "assurance" that the concentration of the luminosity solution (used in the Mechanical Equivalent of Light) was sufficient to eliminate all the infra-red rays, it may be added, in conclusion, that this assurance was given orally, on the assumption that the same thickness of luminosity solution was being used as specified in my published papers [10] which gave the minimum concentration and the thickness of the cell required in order to eliminate all the infra-red when using a solution containing principally cupric chloride as an absorption screen.

WASHINGTON, November 15, 1915.

[10] *Bull. Bur. Standards,* 7, p. 655, 1911; 9, p. 110, 1912.

Motion Models. F. B. GILBRETH and L. M. GILBRETH. (*Proceedings of the American Association for the Advancement of Science,* December 27, 1915, to January 1, 1916.)—A tendency of this age is to think in parts rather than in wholes, in elements rather than in grouped elements. In the olden times both material things and human beings were invariably thought of as entities, wholes; but with closer thinking and the awakening of the scientific spirit of analysis, measurement, standardization, and synthesis has come the realization of the fact that the thing or person as a whole is often far less important than the fact that the thing or person is a group or community or combination of parts. The material thing is analyzed into its elements. The human being is thought of as a group of working members. The old-time operation is thought of as a combination of acts. Now, finally, a motion itself is thought of as a cycle or combination of elements of motion.

While units, methods, and devices of measurement, as applied to education, already exist, there has been a lack of means by which behavior could be accurately recorded, and of the necessary records which might be used as data for predicting behavior, and for outlining methods for obtaining future desired results. Motion models supply this lack. The motion model is a wire representation of the path of a motion in such visible and tangible form that it may be visualized and measured with accuracy, and from such measurement the laws underlying the behavior that caused and affected the motion, and the behavior that resulted from the motion, may be accurately determined.

Graphic Analysis of Building Vibrations. E. E. HALL. (*Electrical World,* vol. 66, No. 25, December 18, 1915.)—Vibrations transmitted to buildings from moving machinery are probably more disagreeable than dangerous in most cases. Outside of congested business districts ordinary vibrations receive little attention, but in installing machinery and foundations under metropolitan conditions the elimination of even slight vibrations is an insurance against possible future difficulties with abutting property owners. The absence of vibration-producing elements in steam turbo-generators is an advantage, often pointed out in this type of power plant, leading to marked economies in the costs of foundation work and even permitting at times attaching the units directly to the framing of the building.

With the very high speeds employed in turbo machinery, the greatest nicety of balance is essential to insure freedom from vibration, and the effects of inevitable imperfection of balance in commercial machines must be reckoned with. An analysis of the vibrations of a reinforced concrete building produced by a turbo-generator connected directly to the walls of the building was made by means of a portable vibration recorder of the type described in *Electrical World,* July 27, 1912, and *Engineering News,* August 1, 1912. The character and magnitude of the vibrations recorded in various parts of the building pointed to the desirability of mounting the prime movers low down and having the foundation of the prime movers separate from the walls of the building. In the type of mounting investigated not only are the vibrations increased but both sides of the suspended floor serve as a sounding-board, and the noise is greater than it would be if the turbo-generator were on the ground floor.

Substituting Copper for Aluminum. ANON. (*Electrical World,* vol. 66, No. 26, December 25, 1915.)—Arrangements have been made by the Rochester (N. Y.) Railway and Light Company to substitute No. 0 stranded copper wire for the 428,000-circ. mil. stranded aluminum conductors of a duplicate three-phase transmission line between Mortimer, N. Y., and the city of Rochester. This line brings 25-cycle 60,000-volt energy from the lines of the Niagara, Lockport, and Ontario Power Company at Mortimer to the city limits of Rochester, a distance of 2.2 miles. The transmission line was built in 1907 and designed to transmit 18,000 horse-power. The span lengths vary from 415 to 550 feet, with a calculated sag of 24.5 feet on the long span at 110°. The No. 0 stranded copper conductors will be strung on the same towers that are used by the aluminum lines, with about the same sag.

While the economic capacity of the two lines has been reduced by the change to about 12,000 horse-power, with the price of aluminum at 56 cents per pound and copper at 20 cents per pound, the basis on which the substitution was made, a net amount of $8400 has been realized from 63,000 pounds of aluminum through the change.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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PORIFERA AND COELENTERATA.

The sponges have been reported several times to show luminosity, particularly in their free embryonic condition. Mangold quotes three such instances, but an examination of the articles so quoted was far from convincing one that the cases have been carefully observed. While the matter is entirely probable, we still lack careful observation and study bringing forth positive evidence. The writer well remembers a tubful of dredgings from the bottom of the Bay of Naples in which sponges were mixed with many other forms. The whole mass glowed for hours after being brought into the laboratory, but a careful examination showed two facts: First, each luminous sponge, when looked at under the microscope, showed several kinds of luminous worms and protozoa distributed through its canals; second, these same sponges taken from other and cleaner bottoms showed no trace of light under the most favorable conditions and severest stimulations. It is not probable that sponges can light.

The coelenterata are one of our oldest and most widely distributed forms of animal life, and histologically and physiologically they have a remarkably uniform and characteristic tissue constitution. Among its characteristics may be mentioned a maximum of fluid in most of the cells, a remarkable general transparency, a tendency to form cell membrane and extracellular jelly, and a distributed physiology due to lack of an efficient medium of circulation.

Thus most of the bodily functions are carried out in simple epithelia, extending over large areas of surface and showing a marked absence of histological amplification (corrugation, evagination, and invagination). As a result of this there are almost no large or involved glands, whose operation and usefulness would be seriously impeded by the lack of circulatory channels and medium.

Since, however, a considerable number of functions, both

* Continued from page 125, January issue.

chemical and kinetic, are possessed by the animals, and since these functions must be distributed for the reasons mentioned above, we find that a section of any of the surface epithelia will show cells of many kinds, and serving corresponding varieties of functions, placed side by side and forming a comparatively complex tissue.

The function of light production is thus found only in the epithelial surfaces of coelenterates, and either distributed over the entire surface, or, as is most commonly the case, restricted to some moderately large area or areas. In no case so far described has any epithelial area been found to be devoted exclusively to light production, but the luminous cells have been scattered more or less thickly among cells of, usually, several other kinds.

The number of the luminous species of coelenterates is large and their distribution in the group is very general. Both the free swimming medusæ as well as the sessile forms, single as well as colonial, show light-producing members among their numbers. It will be convenient to describe a few of the decidedly luminous types in detail and then to draw some generalized conclusions concerning the whole group.

The medusa forms, or " jelly-fish," are well known, and among them is a species, *Pelagia noctiluca* (see Fig. 1), that is perhaps the best-known luminous coelenterate, especially if length of known acquaintance with mankind is counted for this. This large, beautiful species is a common form in the Mediterranean Sea. It is of typical jelly-fish form and swims by a series of rhythmic contraction of its "umbrella," as most of the other medusæ do.

The outer integument is partly colored red or brown. This color is present in various large patches and spots of irregular form separated from each other by narrow bands. The patches and spots are thickened and raised in contour, leaving the bands as depressions or valleys between them.

When this animal is swimming freely at home in the sea at night, or in an aquarium in the laboratory with plenty of fresh sea-water, it gives no light at all. A direct stimulus is necessary to make it show its light. This stimulus may be mechanical, chemical, or electrical. The most powerful stimulus is that with strong corrosive chemicals, as ammonia or some of the mineral acids. They should not be too strong, or the light cells will be killed too quickly.

Under these circumstances a great glow appears that seems to cover the outer surface of the umbrella and the outer surfaces of the larger arms and tentacles. The light is greenish in color and appears to cover the surfaces mentioned above in a rather irregular manner, being somewhat blotched and spotted, but so bright that the outlines of the irregularities cannot be identified. The light lasts for several minutes, dying out slowly (see Fig. 1).

It is with the mechanical stimulation that the light production can be better examined and studied, however. In this case, too,

FIG. 1.

Swimming individuals of *Pelagia noctiluca* as they appeared in the aquarium at Naples. Some had just been struck with a glass rod and were shining. (Original drawing by E. Grace White after descriptions by the writer.)

the animal is neither injured nor killed, and the degree of stimulation can be measured with reference to the amount of light produced.

A slight contact of the finger or a glass rod with the outer surface of the umbrella results in a spot of light at the point touched. This spot is local for only an instant, and then spreads out, but it may not cover the whole surface of the bell. The light appears in lines and streaks and occasionally in patches.

When the contact is made more violently the light is brighter and spreads over the whole umbrellar surface. If violent enough,

the luminosity does not spread, but appears on all the surface at the same time. In this case it is stimulated to appear by the mechanical jar that is communicated through the jelly.

A very noticeable feature of this lighting power is the fact that when one touches the illuminated surface, however gently, the luminous material clings to the fingers and shines on them almost as long as on the umbrellar surface. Thus we have proof that the material is discharged from the cellular tissues (the covering epithelium). If one strokes that surface with moderate firmness, while the animal is resting and not lighting, and withdraws the finger instantly before the light appears, no light will be seen on the fingers, proving that it has not yet been thrown out of the cells. And again, if the outer cells are scraped off, they will illuminate, but the tissues beneath them will remain dark.

These several experiments show that the light produced by the animal is the result of the bringing of a secretion, the luciferine, into contact with the free oxygen in the sea-water, when the luciferine is discharged from the cells that store it. These cells that secrete and store it are undoubtedly some or all of the simple epithelium that covers the outer surfaces of the umbrella and larger tentacles (see Fig. 2). It also seems that the discharge is the result of a nervous reaction following the stimulus, and that this impulse travels through the sub-epithelial plexus of nerves that is characteristic of the coelenterata. The light secretion is always mixed with a larger body of slime which is a mucin. The mucin comes from other and different cells than the luciferine, although it seems entirely probable that the luciferine cells are derived by differentiation from the mucin-secreting cells. In Fig. 2 are shown bits of the epithelium in question in which are drawn the various kinds of cells seen there.

As luciferine is known to often come in the form of granules, it is probable that one kind of the granule-filled cells shown in this figure are the cells under discussion. Further exact work on both the physiology and the structure of this form is desirable. It is not known, among other things, if the production of light is temporarily inhibited by the action of sunlight in this species. Since the luciferine is apparently stored in a granular form, it would seem that this was not the case.

Many other medusa forms are known to give light, although none of them have been as closely studied as *Pelagia*. Dr. L. R.

Cary has told the writer about a cubomedusa, probably a species of *Charybdea,* which was observed in the waters of eastern Jamaica to give off a light from its four tentacles. The light was restricted mostly to these tentacles and was strongest on their ends. Its comparative weakness made it almost impossible to determine if the luminous material was discharged or was consumed in the cells. It appeared to be an intracellular combustion. This same is true of a number of other medusoid forms.

Among these other forms we find three methods of lighting as

FIG. 2.

Portion of a section of the ex-umbrellar surface of *Pelagia noctiluca*, showing several kinds of cells: *l*, luminous cells; *m*, mucin-secreting cells; *v*, empty cells from which the luciferine has been discharged. (Drawn from a section by E. Grace White.)

enumerated by Panceri. First, a number light in the same general manner that the form we have just been studying does, *Pelagia noctiluca.* Such forms are exemplified by *Pelagia phosphorea* and *Cumina moneta.*

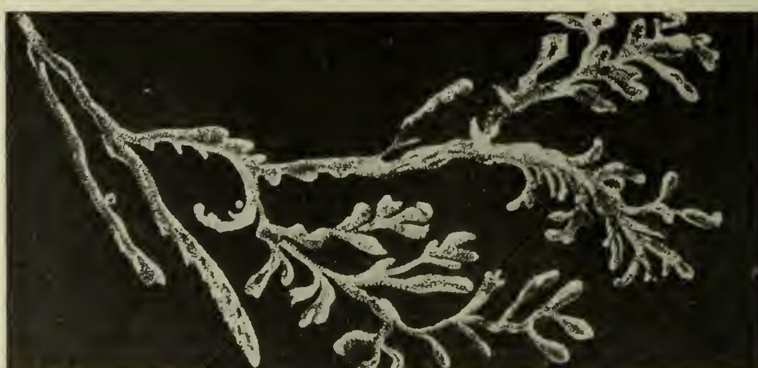
Another group light at the bases of the tentacles, such as *Thaumantias, Mesonema, Lyriope, Geryonia,* and many others. We lack exact work on these forms, except the article of Panceri, which was written in 1871.

The last group consists of several genera, as represented by *Dianæa appendiculata* and *Oceania pileata,* in which the light

comes from the ovaries and from some of the water vascular canals.

A careful study of the cells and tissues at the source of light in several sorts of these groups would undoubtedly enable one to analyze the different sorts of cells and differentiate out the general type of cell that is responsible for the light. According to Panceri, these cells are probably the granule-containing cells mentioned by the writer in connection with the light from *Pelagia*. Panceri worked by scraping the luminous parts, and noted these cells under the microscope in such scrapings. He considered the granules to

FIG. 3.



Drawing to illustrate the appearance of a sea-weed covered by a colony of the campanuarian hydroid, *Campanula flexnosa*. The algæ appear to be luminous. Reduced twice (After Panceri.)

be droplets of fat, in which he was probably mistaken, as we now know that luciferine is not a fat.

The hydroids have been observed in several cases to be luminous, particularly several of the campanularia. Allman describes a luminous form, *Obelia dichotoma*, in which, upon stimulation, the whole colony lights and remains illuminated for several seconds. Panceri studied the form *Campanularia flexuosa* and showed that it lights in much the same way (Fig. 3). It often grows so thickly on algæ (on *Gelidium corneum* and on *Cystoseria ericoides*) that the algæ have been mistaken for luminous plants.

His studies of these forms under the low power of the microscope open up great possibilities as to a method of finding out more about the structures that do the lighting and their method

of lighting. When stimulated while under the microscope he observed that the light appeared as a series of fine dots or points, and he judged that each of these points represented a single cell or some vacuole in that cell. It may be possible that higher powers of the microscope will some time show us more about the lighting methods of coelenterates in this or in some similar form. Fig. 4 shows a branching stalk of one of these hydroids in the luminous state.

Panceri located these cells in the outer layer of the cœnosarc

FIG. 4.

Drawing to illustrate the appearance of a small twig of *Campanularia flexuosa* when lighting in the dark. Magnified twelve times. (After Panceri.)

or in the ectoderm of the animal, and he further showed that the impulse to light is carried by the nerve plexus just under the ectoderm and spreads out from any single point of stimulation in all directions. It even travels from one polyp to the rest, and with this delicate indicator it will be very easy to do some good work on the rate of the nerve impulse in these forms.

The jelly-fish belonging to many of the luminous hydroids are also luminous, but have not been closely studied.

Our next study will be that of light production as observed in the *ctenophores*, a large, homogeneous group of medusa-like forms, quite different in structure from the ordinary jelly-fishes, but well known to all. These creatures are surface-swimming forms found in all seas, and are of extreme transparency and delicacy. Some species have delicate pink and brown or even blue pigments, but most of them are colorless and can with difficulty be seen in the water. The solid content of the tissues is very small, and the creatures are so delicate in structure that even the motion of small wavelets will tear and dismember the bodies of some forms, such as *Mnemiopsis leidyi, Cestus veneris*, and others. A few of them are firmer in composition, such as *Pleurobrachia* and some *Beroe* species.

All the ctenophores have been known for a long time to be light producing. This fact is even well known among the vacationists and travellers, who, when the larger masses of light are seen in the surf or in a tide current or in a steamer's wake, say at once " jelly-fish," or, if they have received an education in which biology has played a part, " ctenophores."

The ctenophores do not show light when at rest. Nor is the motion of their swimming plates accompanied by light. It may be remembered that Quatrefages tried to prove that in the protozoön, *Noctiluca*, the production of light was necessarily accompanied by the production of motion, and *vice versa*. We have positive proof, in studying the ctenophores, as Peters has shown, that the two modes of energy-release are not in any way connected as are the release of motion and heat, or motion and minute quantities of electricity.

The methods of lighting vary somewhat among these organisms. In the world's warmer waters, as seen by the writer in the Mediterranean and on the south Atlantic coast of North America, the light appears as a strong glow, almost a flash, lasting for one or two seconds after mechanical stimulation. The flash stops quite suddenly, and only a faint glow, or lines and spots of weak light, persists for a few seconds longer. In the colder waters of the north Atlantic the flash is longer, and, especially in small and young specimens up to two centimetres in size, the light is a strong, steady glow, lasting for as much as half a minute to a minute (see Fig. 5).

The effects of different temperatures upon the light production

in individual species are of interest and have been carefully studied by Amos Peters on *Mnemiopsis leidyi.* This summer form lives in a sea that in August, at Woods Hole, Mass., has a temperature near 21.5° C. A number of normal animals were first shown to be capable of strong luminosity, and then four of them were gradually cooled by cold water placed around the vessel that contained them, while four others were in a like manner warmed by warm water placed in contact with the dish in which they had been placed. As the cooling and heating progressed slowly the

FIG. 5.

Swimming individuals of the ctenophore *Pleurobrachia pileus* to show the appearance of the organisms as they swim about in the sea in the lighted and unlighted state. (Drawn by the author and E. Grace White from observation on the living animal.)

ctenophores were stroked from time to time in order to observe the effects of the treatments on their capacity for light production.

As the first lot became cooler it was seen that they produced less and less light until 12.5° C. was reached, when no more light was visible under any stimulation. Then the temperature was slowly raised and the power to illuminate slowly returned, showing that it was not death that had caused its inhibition.

This experiment was complemented in a most satisfactory way by the second lot warmed in their original sea-water. As the

temperature rose the light evoked by stroking with the glass rod became less and less brilliant, until at 37° C. no more was given off, even with quite violent stimulation. As this experiment was slowly returned to normal temperature, however, the light power returned until the phenomenon was quite normal again.

Several other experiments along these lines all showed that light production was at its best at the optimum temperature at which the animals usually lived. When the temperature was varied in either direction from this normal optimum, the light power diminished proportionally until it ceased entirely at temperatures, both above and below this optimum, that were not fatal to the creatures' existence.

The influence of daylight upon the luminosity of these forms was also very carefully studied by Peters. Already, in 1862, Allman and, in 1872, Panceri had observed that ctenophores (*Beroe*) would not show their light for some time after having been exposed to sunlight or to bright daylight. Peters further showed that, if they were mechanically stimulated during the exposure to sunlight or immediately after having been brought into the dark, they would recover the power slightly sooner. Thus he exposed two lots of the animals, A and B, to sunlight for about an hour and then brought them into the dark chamber. The lot A was agitated with a glass rod continuously upon being brought in, and began showing light in two and one-half minutes. The lot B was kept in quietness, and at the end of two and one-half minutes a stroke of the glass rod showed no luminous response. But in three minutes they also began to light. Thus the lot A acquired the power to light sooner as the result of a mechanical stimulation.

The two lots were then exposed to light again, A to direct sunlight for two minutes, and B to diffuse daylight. A was agitated as before, and B kept quiet. A lighted in one minute, while B retained the power.

After some minutes both were exposed to daylight, and when brought back into the dark A was agitated and B allowed to remain quiet. A lighted in one minute upon stimulation, and B in two minutes.

Peters thus showed that sunlight not only inhibits the luminosity, but also overcomes a previously-acquired power to light; also that mechanical stimulation accelerates the power to light. By a third experiment on new material he also showed that dif-

fused daylight can check luminosity and that mechanical agitation can accelerate its appearance.

Any periodicity in the lighting power of *Mnemiopsis* due to the alternation of day and night as such, and not to actual light or darkness, seems to be almost lacking. Peters did find a slight increase in light-producing power in night-time over daytime. Such periodicity has been studied in other coelenterates by several observers, as Brooks, Wilson, and Cary. The latter has very kindly allowed the writer to refer to some unpublished observations on the sand-living form of anemone, *Anthopleura cavernata,* found at Beaufort, N. C. Cary placed these creatures in vessels filled with sea-water, which was renewed by a pipe, so that at all times the animals were under the best living conditions. Ten animals were placed in each jar, and one jar was covered so as to be absolutely dark, while the other was left in the light. The normal behavior of these forms is to expand the tentacles at night and to contract them in the daytime. The polyps that were kept continuously in the dark expanded in the night and closed in the day as usual.

The experiment was then tried of bringing several arc lamps in the night-time directly over the jar that was kept open, as well as the one that was kept dark in the daytime. The strong light applied all night made no difference in the behavior of the creatures, which in both vessels kept their tentacles expanded and moving as though it were dark, which it was not.

A number of other physiological periodicities are known among the coelenterata that depend upon the alternation of day and night and are not affected by darkness and light alone. In the ctenophores, however, Peters showed that artificial light and darkness did control the egg-laying activities to a degree, as well as the power of light production.

Thus we see that the inhibition of light production in sunlight or daylight in the ctenophore is a reaction developed almost independently of the several forms of diurnal periodicity in coelenterata, one of which has just been described. It is evidently an economy that is of advantage to the organism, for it requires digested food and cell energy to produce light, and the light could not be of any possible use to the creature in the daytime, when it would not be visible.

Peters also attempted to fatigue the power by continuously

agitating healthy specimens in the dark chamber. Much light was at first given off, but it gradually grew weaker, and at the end of twenty minutes it was very weak, only interrupted gleams being given off. He found it impossible, however, to stop it entirely.

The writer found that at Naples two of the strong flashing kinds of ctenophores, *Cestus veneris* and *Beroe ovata*, gave a strong flash once or twice when continuously stroked with a rod, but that they were apparently exhausted in a few minutes, two or three at the most. At South Harpswell, Maine, in the cold waters of the Gulf of Maine, he observed some ctenophores, a species of *Mnemiopsis*, which were swimming about in floating eel-grass and other flotsam and jetsam in a corner where the wind had collected them. Here the ripples and wavelets were keeping them in a state of continual glow that lasted for over three hours without any weakening; they were still glowing as brightly as ever when the several observers left them at midnight, and they probably were able to keep it up all night.

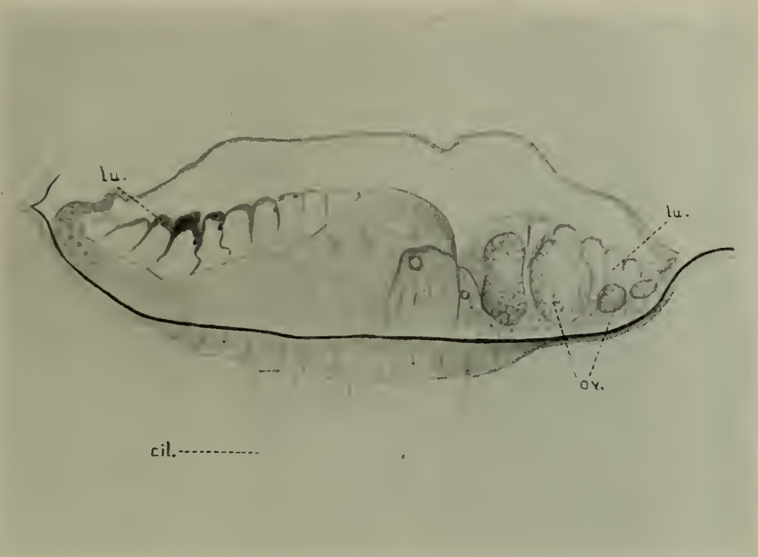
The assumption arrived at from these experiments and observations is that the ctenophores possess light-cells that, under the condition of daylight or any other bright light, do not secrete any luciferine at all, but when placed in darkness begin, after a short period, to secrete it and store it to a very limited degree. Only when mechanically stimulated do they allow it to come into contact with oxygen under conditions that show a light. The natural question now is, Do they thus use it by an intercellular consumption, or, like the jelly-fish *Pelagia* mentioned before, do they cast it out of the cells where it will come into contact with a supply of oxygen? This question can be decided only by a better understanding of the location and structure of the light-cells and their surrounding tissues, and what little of this is known will now be explained.

When a ctenophore lights the glow appears to come from the eight rows of paddles that band its body in the same direction as the stripes on a squash or watermelon. If the finger be rubbed on these glowing lines a certain amount of slime will come off on them, but no luminous material. The first thought is that here we have to do with a form of internal luminosity, the opposite from that condition found in *Pelagia*.

Several observers, however, have watched the lighting very carefully and have seen it apparently come from a line inside of

the paddle plates, and have identified this line as the outer wall of the water vascular tube which is an invagination from the digestive tract. The water vascular tube is lined with an epithelium that has undergone a high degree of differentiation, especially on its wall nearest the paddle plate. Fig. 6 is a sketch of a section of one of these tubes, with its surrounding tissues, to show the general location. This differentiation consists of a modification on one side of the outer wall into a germinal epithelium-producing

FIG. 6.



Low-power sketch of a section of one of the water vascular canals of *Pleurobrachia pileus:* *ov*, ovary; *t*. testis; *cil*, cilia on paddle plate; *lu*, layer of luminous cells covering ovary and testis. (Drawn from a section by E. Grace White.)

ova, and on the other side of a germinal epithelium-producing sperm.

Between the two the epithelium is thickened into a mass of vacuolated cells that appear to spread out on each side over the ova and over the sperm to make a sort of covering for them. It is these cells, with their highly-vacuolated and glandular nature, that have been suspected of being the luciferine-producing cells.

Certainly the light comes from this region; equally surely it does not emanate from the ova or sperm, for both Allman and Peters experimented carefully with this subject, and the latter

showed that the new-laid egg did not light. This leaves two other kinds of cells—the vacuolated cells above mentioned, and certain granulated cells lying at the base of the ovarian epithelium. These latter are easily disposed of by two observations. They cannot be the light-cells, because they stain with osmic acid and are of a distinctly fatty nature. Also, as Dr. E. G. Conklin has told the writer, they are characteristic of the female gonads in several other forms of animals in which no light is produced.

The vacuolated cells found distad of both ovary and testis, then, seem to remain as the most probable source of the light. The vacuoles probably represent the spaces in which some fluid form of luciferine is secreted and stored rather temporarily, and only when the creature is in a fairly complete darkness. Weak evening light, starlight, and even moonlight, do not seem to have the power to inhibit the light production, although Panceri thinks they do.

The cells are of a characteristic shape, as may be seen in the drawing (Fig. 7), and the nucleus is very large, and from its structure appears to be the nucleus of a secretory cell. Certain inclusions in the outer part of the cell (Fig. 7, *in*) might be luciferine, but it seems more probable that the vacuoles are the spaces in which, among other fluids, a liquid luciferine is stored between the time of secretion and of combustion. Peters's experiments with regard to the influence of daylight show one interesting circumstance: the ctenophores will not luminesce in sunshine, nor for some minutes after. If the light for the animal is due to the combustion of a secretion, this seems to mean that the secretory process does not begin until after the animal has been brought into darkness. Again, the secreted material is not consumed until a stimulus (mechanical in this case) has been applied. The flash will not be any brighter or longer even after many hours than it will after the first half hour, showing that only a certain amount of the material is ever stored up. More material is soon stored after a flash is given, and we find it difficult in *Mnemiopsis* to force the animal by repeated agitation to use up its material faster than it can be made. Indeed, Peters showed that this was impossible, although it was greatly weakened at the end of twenty minutes. On the other hand, the writer found that certain warm-water forms at Naples flashed more strongly and were more quickly and completely exhausted.

If now we allow sunlight to fall for a half hour or even less on a healthy ctenophore that has been resting quietly in the dark for a few hours and then return it to the dark and at once attempt to stimulate it to lighting, we would get no light, although we have assumed that it has stored up enough luciferine to do so. One of two conditions must be assumed to explain this fact. One is that the luciferine already present has been resorbed or has changed into non-luminous material, or we must assume that the

FIG. 7.

Two luminous cells from above section, much enlarged to show details of structures: *nu*, nuclei; *vac*, vacuoles; *gr*, granules; *x*, unknown body always found next to the granules in distal part of the cell. (Drawn by E. Grace White.)

sunlight inhibits not the production of luciferine, but instead it inhibits the nerve action that initiates its use; for it is evidently controlled by a nerve action.

Careful study of these probable luciferine-secreting cells seems to show that the combustion is really intracellular. None of the cells seems to have broken nor to have discharged its contents in any way. Also, the large size and segregation of the different (at least three) kinds of inclusions would indicate that the work was done internally. Even in case the secretion of the light-cells

was discharged into the water vascular canal, while we would technically have a form of external combustion, we would actually have the process taking place in a cavity of the animal's body and would not be able to rub off the luminous material on the fingers, as in the case of *Pelagia*.

The eggs of the ctenophores have often been reported to be luminous by earlier writers, but both Peters and the writer have attempted to show this and found it not to be the case. Peters experimented with the developing eggs and found that early segmentation stages would give a single small flash when the dish containing them was jarred, and this was before any cilia had made their appearance. Such a single flash seemed to exhaust the power in these young animals. When the gastrula stage had been reached it was possible to get several tiny sparks in succession, and from then on the power grew.

Mutilation showed but little except that there was no general nerve-centre in control of all the luminous apparatus. When a ctenophore is cut in two or four or much smaller pieces the power to light is retained until the portion is so small as to bear less than four paddle plates. When smaller than this it was observed to be incapable of luminosity, even though still alive and with its one, two, or three paddle plates in active motion, showing that it was still alive.

Among the Actinozoa, one group, the Pennatulidæ, are noted for their strong luminosity. These organisms are colonies of individuals arranged in rows on a feathering stalk (see Fig. 8) and provided with a common muscular foot which digs and moves in the sand or mud and carries the whole colony about to favorable locations. Sea-pens or sea-feathers they have been called, and the resemblance can easily be seen in the figure.

The luminosity of these creatures has been mentioned or briefly described by Gesner in 1555, Imperati in 1672, and in later times by Shaw, Grant, Ellis, Tilesius, and Blainville. Spallanzani, in 1798, told how the sea-pen shone when it was shaken, and how the light came from the single polyps on its branching arms. In his thorough, scientific way he even showed that the luminosity was in the discharged slime from the animal's body. Rapp, in 1829, again called attention to the fact that the luminous material was in a slime that was discharged from the body surface of the polyps and which stuck to and shone on the fingers of a hand that touched the creature. Della Chiaje described how the light

progressed from either tip to base or base to tip, according to which point first received the stimulus.

FIG. 8.

Drawing to illustrate the appearance of *Pennatula phosphorea* when in its habitat and shining. (Drawn by Bruce Horsfall from descriptions by the author.)

Panceri, who has told us so much about the luminosity of animals, also worked on the Pennatulids and studied their reac-

tions while lighting. He found that the luminous tissue consisted of masses of cells placed in the forms of cords or bands on the outer wall of the stomach and reaching into papillæ surrounding the mouth. This seems to be an unusual position in any coelenterate, and should be studied by more modern methods in conjunction with a study of those jelly-fish that have the light tissue situated on the ovaries.

There are eight of these cords placed between the mesenteries, and they evidently have intimate nervous connections with each other as well as with the general nervous system of the colony. The cells of these cords contain, according to Panceri, numerous fat droplets, which we must again interpret as granules of luciferine.

As already mentioned, Panceri also showed that the lighting proceeded from any point of stimulation in all directions. If one injured or touched the base, a line of light travelled up and spread out on each row of polyps as it advanced up the main stem. The same was true of any stimulation of the tip of the feather-like colony. Again, if the end of any such branch was stimulated the lighting proceeds down that row to the stem and then travels up and down the stem and out on the other branches in the same way. The speed of these waves or nerve impulse is about 20 seconds for one metre. Wagner has reported a more general luminosity on the stem and foot of Pennatula which others deny.

The light produced by the pennatulids is quite different in most cases from that shown by the jelly-fishes and hydroids. While that of the latter is usually greenish and white, and while the ctenophores show a brilliant emerald-green light, the different reports concerning the various kinds of pennatulids show that their light ranges from " silvery-white " to lilac or violet.

Wyville Thompson dredged many large specimens of *Pavonaria quadrangularis* from deep waters off the coasts of the British Isles. Often it was dark when the dredge came up and over the side of the ship, and he describes the " pale lilac " light shown by these animals as they came up through the water and were thrown on the deck. This observer had the additional advantage that usually there were many specimens of an ophiurian, *Ophiacanthia spinulosa*, in the dredge together with these pennatulids, and the ophiurians were shining with their green light, thus giving him the opportunity of an actual comparison, a most necessary condi-

tion when matching or describing colors, as all know. The light of the pennatulids was further compared in its color to the flame of cyanogen gas, and it was a constant light which most probably had been shining for some time, as the animals were torn from the bottom and hauled up through the hundreds of feet of intervening water.

Panceri describes the light of another pennatulid, *Cavernula pusilla*, as a lively blue. Agassiz describes the light of our American shallow-water *Renilla* as golden-green.

The siphonophore medusæ are reported to give a light by both Panceri and Giglioli. The latter mentions the genera *Praya, Diphyes, Abyla*, and *Eudoxia*. Tilesius includes *Physalia* among the forms that illuminate, but others have denied it. No careful work has been done on these forms, whose delicacy and rarity make them difficult to work on, especially at night. The color of the light has been mentioned as of various unusual shades, as red and violet. The colors of the weaker exhibitions of light are sometimes hard to distinguish, and the writer has observed in many luminous animals that the first weak flashes that precede a stronger exhibition are of a deep violet color.

Of other coelenterates we have mere statements or casual observations which show that gorgonians and corals are luminous. In some few species of Antipatherians as well as a species of *Mopsea* and of *Isis* a luminosity was observed by De Folin. It was very bright and one could read the finest print at a distance of eighteen feet from a tub full of dredgings in which these forms were abundant. Monaco saw several forms of corals that were luminous.

In general we may say that a very large number of coelenterates show light, that it is usually weak in comparison to that of the stronger light shown by some other creatures, and that it shows variations as to position of luminous tissues and method of bringing the luciferine into contact with the reagents that cause it to illuminate.

(*To be continued.*)

Higher Steam Pressures. R. CRAMER. (*Proceedings of The American Society of Mechanical Engineers*, December 7 to 10, 1915.)—Since the laws of thermodynamics have been recognized by engineers as a sure guide to improvement of heat engine economy, there has existed a tendency to increase the temperature range of

the working fluid; that is, to increase the temperature at which the working medium absorbs heat and lower the temperature at which it rejects heat. This has led, in steam engine practice, to the recognition of well-defined limits imposed by operating conditions; namely, a maximum temperature of 600° F. and a minimum of 80° F., corresponding to a pressure of one-half pound per square inch, or 29 inches of vacuum.

In the best present-day practice the maximum steam pressure is 200 pounds per square inch, absolute, with a superheat of 200° F. The corresponding temperature of evaporation is 382° F., and the bulk of the heat is absorbed at a temperature 200° F. below the maximum. It seems reasonable to expect that the approximation to the ideal Carnot cycle, and simultaneously the economy, would be improved by using higher pressure and less superheat; that is, by increasing the temperature at which the bulk of the heat is absorbed without increasing the maximum temperature. Steam pressures might be increased to 600 pounds per square inch without using temperatures higher than those employed in modern practice, and the difficulties encountered by the designer would not be formidable and would be more easily met than those of some types of explosion engines which have been successfully designed.

Parallel Packing of Nails by Electricity. ANON. (*Scientific American*, vol. cxiv, No. 2, January 8, 1916.)—Heretofore no attention has been paid to any order in the packing of nails in the container; they have been dropped loosely in the keg, the pieces locking and interlocking in a hopeless tangle. Now, however, with the aid of a special machine, nails can be nicely and accurately arranged in a box parallel to each other, so that their removal by hand is a simple matter. The greatest advantage of the new method is that the nails systematically laid in a box will occupy little more than half the space required when they are dropped in the keg. The boxes filled by the machine have a capacity of fifty pounds and are no larger than a five-pound confectionery box.

The machine is of German origin and is just being introduced into this country. Its operation is based upon the principle that linear iron articles when brought into a magnetic field will automatically take a position parallel to the lines of force. The machine consists essentially of the electric paralleling mechanism, a feeding trough and shaking device. By means of the latter the nails glide gradually into the paralleling mechanism and, while still falling, are drawn in the direction of the lines of force. The nails are passed into a tray fixed between two magnetic poles, and at intervals the tray is pressed downwards and the contents emptied into boxes. With but little adjustment the machine may be made to handle any size of nail. The paralleling mechanism uses direct current at 110 or 220 volts.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE "CENTRE OF GRAVITY" AND "EFFECTIVE WAVE-LENGTH" OF TRANSMISSION OF PYROMETER COLOR SCREENS, AND THE EXTRAPOLATION OF THE HIGH TEMPERATURE SCALE.[1]

By Paul D. Foote.

[ABSTRACT.]

An equation has been derived representing, as a function of the temperature of the black-body source sighted upon, the "effective wave-length" of any pyrometer color screen or system of color screens, or of color screens used in combination with sector disk, nicol prisms, or absorption screens. Attention is called to the difference between the "effective wave-length" and the "centre of gravity" of the luminosity curve, as the so-called centre of gravity of the color screen has been in the past sometimes considered the true effective wave-length. When an absorption glass, nicol prisms, or sector disk are used with a pyrometer employing light which is not strictly monochromatic, such as the Holborn Kurlbaum instrument, for the object of reducing the brightness of the sources sighted upon, the relation between the true temperature ϑ and the measured temperature S is of the form $1/\vartheta - 1/S = A$, where A has been heretofore considered a constant. Actually, it is shown, A is an important function of the temperature of the source. The consideration of A as a constant may introduce errors as great as 40° or 50° at 3500° if the absorption device is calibrated in the usual manner. When two or more absorption glasses are used together, it is not permissible to assume that the value of A for the entire system is equal to the sum of the values of A for the glasses used separately. It is shown that the combination of a sector disk and absorption glass gives a value of A which is practically independent of ϑ.

* Communicated by the Director.

[1] Scientific Paper No. 260.

MAGNETIC TESTING.*

[ABSTRACT.]

This circular deals with the fundamental magnetic quantities, the data required for ordinary engineering purposes, the scope and methods of magnetic testing at the Bureau of Standards, typical data of magnetic materials, and with empirical formulas connecting the magnetic quantities ordinarily used. It also gives magnetic constants for the elements, as well as for some of the more important compounds.

The fundamental magnetic quantities are those commonly used in engineering or technical work. Definitions are given and the question is considered as to what extent the complete magnetic data must be given to define the magnetic characteristics of a material.

The scope of the work of the Bureau in magnetic testing is outlined, giving the size of test-pieces required and the data ordinarily required for various engineering needs. The methods of testing are described in some detail, calling attention to the difficulties and sources of error and the importance of proper sampling.

Typical data and curves are given for representative materials in commercial use. These include materials for permanent magnets, electromagnets, armatures, transformer cores, etc. A table is also given showing the magnetic susceptibility of the chemical elements, together with a few of the more important compounds.

Considerable attention is given to an analysis of some of the empirical formulas which express the relations between the various magnetic quantities. These formulas are useful in indicating the behavior that may be expected of materials under conditions other than those under which they have been tested.

Finally a list of the Bureau publications on magnetic subjects is given. These publications are issued in pamphlet form and will be sent upon request.

* Circular No. 17.

STANDARD TABLES FOR PETROLEUM OILS.*

Samples of both crude and refined petroleum were collected from the different oil fields of the United States, and their densities measured at temperatures between 0° and 50° C. On a part of the samples the measurements were made up to 85° C.

The investigation has shown that for practical purposes the rate of expansion of petroleum oil is a function of density and temperature only.

From the data obtained extensive tables have been prepared for reducing to the standard temperature the values of specific gravity, volume, and Baumé degrees observed at other temperatures. Tables have also been prepared for showing the relation between specific gravity, Baumé degrees, and pounds per gallon.

THE DETERMINATION OF BARIUM CARBONATE AND BARIUM SULPHATE IN VULCANIZED RUBBER GOODS.†

By John B. Tuttle,
Associate Chemist.

[abstract.]

Specifications for purchasing rubber goods frequently permit the use of barytes (barium sulphate) as a mineral filler without having the sulphur which it contains count as part of the specified total sulphur. In such cases the barium sulphate must be determined in order to properly correct the total sulphur.

When barium sulphate only is used, the amount present is readily ascertained by determining the total amount of barium present. If barium carbonate is used, it is necessary to separate the two salts. By means of tests made on compounds of known composition prepared at the Bureau of Standards, a method has been devised which permits the quantitative determination of barium carbonate in the presence of either lead sulphate or barium sulphate, the two sulphates most commonly used in rubber goods. The accuracy of the determination is satisfactory for all practical purposes.

* Circular No. 57.

† Technologic Paper No. 64.

SOME QUALITATIVE TESTS FOR GUM ARABIC AND ITS QUANTITATIVE DETERMINATION.*

By C. E. Waters and J. B. Tuttle.

[abstract.]

As might be expected from their chemical nature, the gums do not readily lend themselves to reactions of a definite qualitative or quantitative value. The object of this paper is to bring together the most important methods that have been published, with more or less discussion of each, and to present a new procedure for the determination of gum arabic. Reference is made to numerous attempts to find qualitative methods that would be at least as satisfactory as those which were not new. It was found, however, that basic lead acetate gives the most characteristic reaction. Mixtures of neutral ferric chloride and alcohol, and of copper sulphate and sodium hydroxide are of value as confirmatory tests. Dextrin and gum ghatti, which is in many respects similar to gum arabic, behave toward these reagents quite differently from the latter gum and from one another.

Heating with potassium hydroxide, color reactions with phenols and a considerable variety of other reagents were found to give indications of no value.

For the quantitative estimation of gum arabic there have been suggested several methods, to all of which some objection can be made. Ferric chloride with calcium or sodium carbonate, lead acetate, alcohol, and copper sulphate with an alkali have been proposed as precipitants. Of these the reagents that yield precipitates easy to handle are not specific for gum arabic. Other methods depending on hydrolysis or oxidation have been found wanting.

After numerous trials of copper sulphate and alkali, as well as of modifications of Fehling's solution, the authors found that satisfactory quantitative results are obtained by the following procedure. Dissolve 50 grammes of copper acetate in water, add an excess of ammonia, and dilute to 1000 c.c., using water and alcohol in such proportions that the final solution contains 50 per cent. of alcohol. For each determination, 50 c.c. of a solution containing about 0.25 gramme of gum is pipetted into a 250-c.c. beaker, an equal volume of alcohol is then added, and finally 25 c.c. of the copper reagent, with constant stirring. The

* Technologic Paper No. 67.

precipitate is allowed to settle, is filtered on a tarred paper, washed with 50 per cent. alcohol containing ammonia, then with 75 per cent., and finally 95 per cent. alcohol. It is then dried to constant weight at 105°, ignited in a porcelain crucible, and the ash weighed. The amount of ash deducted from the weight of the original precipitate gives the "net gum arabic." The amount of moisture in the gum originally taken for analysis must be allowed for. This is determined by drying in a stream of hydrogen at 105°. The percentages of gum found in a series of 18 determinations averaged 99.5 per cent., the extreme values being 96.6 and 103.3 per cent.

THE DETECTION OF RESIN IN DRIER.*

By E. W. Boughton.

[abstract.]

Although the distinction is not always recognized in the paint trade, oil driers differ from japan driers in that the former contain no resin. The introduction of any considerable amount of rosin into a paint by the addition of a drier containing rosin makes the paint unsuitable for outside work, but it is improbable that the substitution of a japan drier, free from rosin, for an oil drier, or *vice versa*, makes any noticeable difference in paint films, if the drier is added judiciously. Resin may be detected in drier by the following methods: (1) Test for rosin by the Liebermann and Storch test. (2) Treat 0.2 gramme of the mixture of unsaponifiable matter, fatty acids, and resin acids, obtained from the drier, with 5 c.c. of 97 per cent. alcohol. A marked turbidity or a deposit of insoluble matter shows the presence of resin, but rosin in small amounts of Kauri cannot be detected in this way. (3) Treat a one-gramme portion of the mixture of fatty acids, resin acids, and unsaponifiable matter with absolute alcohol and concentrated sulphuric acid (Wolff's method), and by titration with 0.25 N alkali determine the acid number (mg. of KOH per gramme of the mixture of unsaponifiable matter and acids taken) due to unesterified acids. An acid number of over 10 shows the presence of resin. By this procedure resin can be detected when the amount is at least 6 per cent. of the ash-free non-volatile portion of the drier.

* Technologic Paper No. 66.

Platinum Substitutes in Lamp Making. ANON. (*The Journal of Industrial and Engineering Chemistry*, vol. 8, No. 1, January, 1916.)—An incandescent lamp must be hermetically sealed and yet must have current led through its walls to the filament. From the beginning this has been effected by sealing two platinum wires through the red-hot glass, all other methods having been quickly discarded. Lately, however, sundry substitutes for all-platinum seals invented by Byron E. Eldred have, to all intents and purposes, displaced the use of platinum. These seals have proved not only as good as platinum, but better.

In sealing a wire through glass two things come into play, one being the adhesion of the metal and the glass, or what is termed the "wetting" of the metal by the glass, and the other the relative expansion and contraction of the metal and the glass. Softened or fluid glass "wets" platinum readily. This may be in part due to the specific physical affinity of the molecules of glass for the molecules of platinum, and may in part be due to the fact that the platinum maintains a metallic surface during the sealing operation.

The expansion of glass, however, is somewhat more than platinum, even with the soft glasses which are often used for lamps. The difference is not great, but it exists. The net result in cooling a platinum glass seal from a high temperature to a lower temperature is that the platinum tends to shrink away from the glass. This shrinkage is not great, but it is responsible for a little strain—a strain which is resisted by the adhesion of the glass and the platinum. Mr. Eldred conceived the idea of doing away with this condition of tension by making a wire whose expansion was a little less, but not much less, than that of the glass to which it was to be sealed. With a wire of this kind, on sealing and cooling, the glass shrinks down on the wire and there is a little compression in the seal. The amount of this compression must not be great, since otherwise dangerous strains might exist, but a little compression there should be. He devised a type of wire having a core of nickel-steel of very low rate of expansion, a jacket of copper on the core, and a further jacket of platinum on this copper sheath. The composition of the nickel-steel was so chosen that its own expansion, averaged with that of the copper and the platinum, gave the wire, as a whole, a little less expansion than that of the glass, so that, in sealing, the desired shrink-on effect or compression seal could be attained. The function of the copper in this combination was not only to give a greater electric conductivity—something much needed in these small-gauge leading-in wires—but also to make more regular the expansion of the nickel-steel. While nickel-iron alloys can be made to have any expansion within a certain range that may be desired, this expansion is not regular through the range of temperature incident to the sealing-in. The copper serves to make this curve of expansion more regular.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting held Wednesday, January 19, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 19, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 36.

Mr. G. H. Clamer, Chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The tellers of election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-Presidents, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Louis E. Levy, Vice-President (to serve two years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, Robert S. Perry, E. H. Sanborn, Managers (to serve three years).

Kern Dodge, Manager (to serve two years).

William C. Wetherill, Manager (to serve one year).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1915, with the Reports of the various Committees of the Institute and Board of Managers (appended).

Dr. Melville E. Stone, General Manager, The Associated Press, New York City, was introduced and addressed the meeting on the subject of "Supplying the World with News."

He described the early attempts at news-gathering, beginning with those of Samuel Topliff, of Boston, Mass., in 1812, and followed later by the New York Associated Press, the Western Associated Press, and finally by The Associated Press with its nine hundred members. Mention was made of the various foreign agencies which coöperate with The Associated Press in obtaining the world's news for the daily press. The methods of collecting such news and distributing it throughout the United States were fully described, and incidents were related illustrative of the work of the organization and the rapidity with which news items are obtained and transmitted from various parts of the world. After a discussion, in which Messrs. Henderson, Bond, Clark, Sellers, Levy, and others took part, the thanks of the meeting were extended to Dr. Stone.

Adjourned.

R. B. OWENS,
Secretary.

PRESIDENT'S REPORT AND REPORTS OF THE COMMITTEES OF THE INSTITUTE AND THE COMMITTEES OF ITS BOARD OF MANAGERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915

REPORT OF THE PRESIDENT

To the Members of The Franklin Institute:

In presenting this report under authority of your Board, I make the fact that just a decade of time has elapsed since I first had the honor of speaking to a meeting of The Franklin Institute my excuse for prefacing the more formal portion of the report with some of the thoughts on the Institute and its past, which naturally come to me at this time.

Ten years ago to-night for the first time I had occasion to thank the membership of The Franklin Institute for the honor of election to the office of President. Each third Wednesday in January, through the intervening years, I again have had reason to thank you for your expression of confidence, and have felt more deeply the honor conferred upon me, and more deeply the responsibility that the honor brought with it.

Naturally, at the end of the decade my mind runs backward over the intervening years. The ten years that have elapsed since I first occupied this chair have seen profound changes in the Institute and in the personnel of its management. To-night I, as a member of the Institute, mourn—as must you—the loss of many good friends; men whose contributions to the work of the Institute were valuable and timely; men, some of them, who had grown old in the service of the Institute, and whose going has added to the difficulties of maintaining the standards they had helped to establish. Few indeed of the men who were carrying on the work ten years ago are now with us. Of the twenty-four members of the present Board of Managers, whose report this is, but five were members a decade ago. To-day there is no living ex-president of The Franklin Institute. John Birkinbine, for ten years the president and throughout his life an hereditary friend of the Institute, has died since our last annual meeting. We miss him and we mourn him.

There is one living ex-secretary of The Franklin Institute—Dr. Isaac Norris, Jr., who served three years, thirty-five years ago. Dr. Norris is now the oldest member of the Board, in point of service. Dr. William H. Wahl, that talented gentleman who knew not when to rest if there was any work for the Institute to be promoted, died in 1909 after thirty years' service as secretary. Following Dr. Wahl's retirement from the position of secretary—a retirement forced by ill-health—James Christie undertook to fill in the gap between the retirement of Dr. Wahl and the selection of a permanent successor. Mr. Christie died in 1911, and there are few men whose decease the Institute has had more occasion to mourn.

There is no living ex-actuary of The Franklin Institute. Herbert L. Heyl, who was the actuary at the beginning of the period we are discussing, and

who died in 1908, was temporarily succeeded by James Christie, who undertook the duties for a brief period, giving his services here, as in the office of secretary, without compensation.

There is no living ex-treasurer of The Franklin Institute. The distinguished Samuel Sartain, who was treasurer from 1883 to 1906, died in the latter year, and was succeeded for a short period by Dr. Wahl, and later, in 1908, by Cyrus Borgner, whom you have just re-elected.

There is no living ex-librarian of The Franklin Institute. Alfred Rigling, the present and efficient librarian, has occupied the position since 1887.

Mr. Henry Howson, senior vice-president; Mr. Alfred Rigling, librarian, and the president, are, among the executives of the Institute at the time of my first election to the presidency, the only survivors. The many losses that death has forced upon us during the decade have brought us sorrow.

And a sorrow, heavy indeed, has come upon us this year through the death of James Mapes Dodge—for twenty years a manager, and, at the time of his death, senior vice-president of the Institute. You have just elected his son, Kern Dodge, to the position on the Board made vacant by the death of his distinguished father.

In its financial affairs the Institute has prospered during the decade just elapsed. Ten years ago we were running to an annual deficit of thousands of dollars. We confidently expect that for the year we are just entering the income of the Institute will be equal to its outgo; and we believe that, with the fulfilling of the conditions imposed by the Wahl bequest—which matter is entirely in the hands of its friends—the Institute will have an income justifying it in the occupation of its hoped-for and confidently-anticipated new structure on Logan Square.

The Managers of your Institute would be proud if they could claim that the greatly-improved financial condition of the Institute was due to their efforts. There are generous men connected with the management who have liberally helped the Institute in its time of need, and indeed I could name a few to whose liberality the continuation of the work of the Institute, through what I believe must have been the most trying period of its existence, was mainly due. But the large sums of money that have come to the Institute in the last few years have not come from the personnel of the management. They have come, as legacies, from people who have known the Institute and of its work, and who, seeking to leave some portion of their wealth where it would help to promote the interests of mankind, have selected The Franklin Institute as a fitting instrument to the accomplishment of that end.

The work of the Institute during the decade has been carried on with a success that perhaps has varied, but has certainly never been a negative quantity. The temptation to embark in new fields of activity has been constantly and successfully resisted. The efforts of your Managers have been to do better the work which their predecessors had done well, and to extend the radius of its beneficial influence.

Attached to, and forming a part of, this report are the several reports of your Board's and the Institute's committees, which give in detail an account of the Institute's various activities for the fiscal year ending September 30, 1915.

From a perusal of them the gratifying conclusion is reached that the usefulness of the work of the Institute is well maintained.

Gratifying as is our Finance Committee's report, as compared with its reports of previous recent years, it does not tell the whole story of our present financial condition. Your Board are glad to be able to tell you that since September 30, the date of the expiration of our last fiscal year, the Institute has come into possession of the Shippen Bequest, the income from which, added to the income from other sources, represents an amount equal, or practically equal, to the Institute's current annual expenses, and this despite the fact that such expenses have been greatly increased in recent years. In a word, referring only at the moment to the Institute's financial condition, it may be said that the Institute is operating, for the first time in perhaps fifty years, with practically no annual deficit.

But if the Institute's work is to expand and increase in usefulness, as it assuredly should, and if we are soon to begin the erection of the necessary new and larger building or group of buildings, our present annual income is not sufficient. How to increase the Institute's annual income has been, as you can imagine, a constant concern of your Board and of others equally interested in its welfare. Certainly, one great opportunity affords at the moment, and that opportunity is the meeting of the conditions of the bequest made to the Institute by its late distinguished secretary, Dr. William H. Wahl. The value of Dr. Wahl's estate is some $90,000, which comes to the Institute when an equal sum is subscribed by its friends, and provided such sum is subscribed before the 16th of December next. To the present, only some $25,000 have been subscribed to what we are calling our Wahl Fund. Some $70,000 to $75,000 more are necessary to meet the conditions of this bequest, and your Board cannot too strongly urge the Institute's friends to see that such an amount is subscribed as soon as possible.

With an increase in its productive funds of nearly $200,000 the Institute will be in this financial position—it will have an annual income which will warrant it in going into a new and much larger building, urgently needed for its increasing activities. The Institute owns, and has held in trust for it, what is generally considered the best building site for its purposes in Philadelphia—all paid for and free of liens; and it has something over $200,000 towards the erection of the first building—complete plans and model of which are now being prepared by the architect of the Institute, Mr. Windrim.

Brighter hopes for the future this Institute has probably never had, but their materialization is dependent upon the efforts of the members in its behalf, and in the near future.

Notable among the happenings at the Institute during the past year was the awarding of the first Franklin Medals to Mr. Edison and Professor Onnes, from a fund generously founded by Mr. Samuel Insull, of Chicago.

Your Board believe that the way in which the work of your Science and Arts Committee in encouraging, by various recognitions, invention and scientific discovery is being performed well merits your approval.

You have doubtless observed with pleasure the change in the physical features of the Institute's JOURNAL, which appeared in its new form on January first. Your Committee on Publications should be congratulated on

the success of its efforts to make the JOURNAL, in its mechanical structure, worthy to be the vehicle of the notable writings presented upon its pages. Another feature of the JOURNAL, though not an accomplishment of the past year, is worthy of repeated mention. It is the list of eminent men acting as associate editors. This body of distinguished advisers is a creation of the past few years, and the services of these men are of inestimable value to the JOURNAL, to its readers, and to the promotion of the mechanic arts.

As in previous years, men among the most distinguished in science and technology, in this and other countries, have addressed your meetings and have discovered to you and your friends the latest achievements in the scientific and technical world.

Your library—more cramped for space than ever, by recent valuable accessions—has been rearranged, with the result of increased usefulness.

Your School of Mechanic Arts has flourished and plans are under way for its enlargement.

Your Board hopes that each member of the Institute will read the reports of the committees and so learn more of the condition of the Institute, and of the work done by it, than can be told in the report of the Managers.

The work of these committees and the usefulness of the Institute generally are hampered by two conditions: by lack of space and by location of building. With the one ambition to be of greater service to the citizen and to the State, your Board, and all the workers in our honored institution, urge upon the membership to cut the only fetters which bind it, by raising at once the fund necessary to insure the acquisition of the Wahl Bequest.

Respectfully submitted,

For the Board of Managers,

WALTON CLARK,

President.

PHILADELPHIA, January 19, 1916.

REPORT OF THE COMMITTEE ON LIBRARY

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

There were expended during the year $928.66 for the purchase of 266 volumes, 2 pamphlets, and 2 diagrams; $1626.25 for subscriptions to magazines and other periodical publications; $824 for binding, rebinding, and repairing of books, and $4821.11 for salaries and general expenses.

There were available for meeting these expenses $7232.76 appropriated by the Board of Managers and $967.26 being the income of the several library funds.

The accessions by gift and from the JOURNAL amounted to 1227 volumes, 1470 pamphlets, and 7 maps.

There was an increase of over 600 titles in the additions of the year when compared with the previous year. This is due chiefly to the continuance of

the practice of applying to engineering firms, industrial establishments, and others for copies of recently-published catalogues and books.

The sorting of the great collection of pamphlets was finished during the past summer. All of a non-technical nature were put aside, and in July 21,100 on medical, historical, and political subjects were transferred to the Free Library. The total number of pamphlets in the library on September 30, 1915, was 29,327. These relate to various branches of technology and science, and the work of preparing them for binding is now under way. Those relating to mechanical subjects will be catalogued at once and will be followed by the other classes.

The following disposition was made of the accumulation of duplicates and non-technical books:

500 volumes of non-technical works, duplicates, and government reports were transferred to the Free Library.

44 volumes of similar material, valued at $32, were transferred to another library to close an old exchange account.

141 volumes were sold for $40 cash.

There are at present only 8 duplicate volumes in stock.

On September 30, 1915, the library contained 67,436 volumes, 29,327 pamphlets, 2288 maps and charts, and 1336 photographs.

The work of preparing the list of current periodicals is nearly finished. Certain checking is now being done to bring it up to date. This list on cards will show the condition of every periodical set in the library. It will give the date when the publication was first issued, the number of volumes, any changes in the title, and the frequency of its appearance. Where the set is not complete, the wants will also be given on the cards. On the completion of this work lists of wants will be issued which can be distributed to second-hand booksellers and magazine dealers. It will then be possible, in the course of time, to complete all the important serials in the library.

The question of binding is still a serious one, but the amount appropriated for this purpose is being expended on such books as are consulted most frequently. A detailed statement of the work of the binder appears elsewhere.

The Committee held meetings each month during the year, excepting in July and August. Many problems connected with the management of the library were given consideration, and books submitted for purchase were carefully examined before being ordered, or were referred to such experts as were willing to aid the Committee in its selections.

The attendance in the library has been as good as heretofore, and a still further increase is noted in the attendance in the evenings.

A detailed statement of the operation of the library is appended hereto.

Respectfully submitted,

CLARENCE A. HALL,

Chairman, Committee on Library.

PHILADELPHIA, January 12, 1916.

APPENDIX.

The following additions were made to the library during the twelve months ending September 30, 1915:

	Bd. Vols.	Unbd. Vols.	Pphs.	Maps	Diagrams
By Gift	626	572	1463	7	
JOURNAL	25	4	7		
Binding	476				
Chemical Periodicals Binding Fund	30				
Purchase:					
Books and Periodicals Account	31	1	1		
Income: Lea Fund	31	3	1		
Moore Fund	134	19			2
Morris Fund	29				
Potts Fund	12	6			
	1394	605	1472	7	2

Total additions for the year 3480

Gifts of books, pamphlets, periodical publications, and maps and charts in large quantities or of special value were received from:

Messrs. N. W. Akimoff, W. D. Anderson, H. M. B. Bary, Miss Booth, The Cassela Color Company, Mr. George S. Cullen, The Engineers' Club, Messrs. Spencer Fullerton, Richard Gilpin, Clarence A. Hall, Prof. L. M. Haupt, Messrs. Harris & Richards, Messrs. Helme & McIlhenny, Drs. Carl Hering, Charles F. Himes, Harry F. Keller, Henry Leffmann, Mr. F. N. Morton, Miss Peuckert, The Philadelphia Book Company, Messrs. L. E. Picolet, C. W. Pike, Mrs. Max Riebenack.

The Committee is again indebted to Mr. Joseph A. Arnold, Editor and Chief of the Division of Publications, U. S. Department of Agriculture, for copies of current publications of the Department.

BINDING.

The work done in the bindery was as follows:

	Bound	Repaired	Rebound
Recent volumes of periodicals	476		
Recent volumes of periodicals charged to Chemical Periodicals Binding Fund	30		
Old volumes		1	3
Books purchased with the income of:			
Moore Fund	1		1
Morris Fund		1	

REPORT OF THE COMMITTEE ON MUSEUMS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

The following models and apparatus have been added to the Institute's collections:

15-Kilowatt Multiple Magnet K-type Edison Dynamo. Gift of the Wm. Cramp & Sons Ship and Engine Building Company.

Rotary Steam Engine. Gift of the Herrick Engine Company.

Original apparatus used by Dr. Edwin F. Northrup in his experiments and investigations on vortex motions in liquids. Gift of Dr. Northrup.

Early form of Berliner Gramophone. Gift of Mr. Henry Howson.

During the year the front south basement room was cemented and the large models were assembled and set up. Shelving was placed on the south wall for small models and apparatus.

The various exhibits in the Committee's care have received proper attention and are all in good order.

Respectfully submitted,

Alex. E. Outerbridge, Jr.,
Chairman.

Philadelphia, January 12, 1916.

REPORT OF THE COMMITTEE ON MEETINGS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

Eight stated meetings were held during the year with an attendance of 1515 members and visitors.

At the May meeting the first presentation of the Franklin Medal was made to his Excellency, Chevalier van Rappard, on behalf of the Royal Netherlands Government, for Prof. Heike Kamerlingh Onnes, of the University of Leiden, and to Thomas Alva Edison, Esq., of Orange, N. J. A bronze replica of the artist's model of the Franklin Medal was presented to the Institute by the sculptor of the medal, Dr. R. Tait McKenzie, and another replica was presented by the Institute to Samuel Insull, Esq., of Chicago, Ill., founder of the medal fund. After the meeting a reception was tendered to his Excellency, Chevalier van Rappard, and Messrs. Edison and Insull in the rooms of the Historical Society of Pennsylvania.

The following papers were presented during the year:

October 21, 1914.

"The Earth a Great Magnet." Dr. L. A. Bauer, Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

November 18, 1914.

"The Photography and Analysis of Sound Waves." Dr. Dayton C. Miller, Professor Physics, Case School of Applied Science, Cleveland, Ohio.

December 16, 1914.

"An American Engineer in China." Dr. William B. Parsons, Consulting Engineer, New York City.

January 20, 1915.

"Conditions Affecting the Success of Main Line Electrification." Mr. William S. Murray, Consulting Engineer, New York, New Haven and Hartford Railroad, New Haven, Conn.

February 17, 1915.

"Sanitation and Accident Prevention in Industry." Dr. Francis D. Patterson, Director, Department of Sanitation and Accident Prevention, Harrison Bros. & Co., Inc., J. G. Brill Company, and Electric Storage Battery Company, Philadelphia.

March 17, 1915.

"High Temperature Investigations." Dr. Edwin F. Northrup, Palmer Physical Laboratory, Princeton, N. J.

April 21, 1915.

"Mechanical Stoking of Locomotives." Mr. W. S. Bartholomew, President, Locomotive Stoker Company, Schenectady, N. Y.

May 19, 1915.

"Electricity and Modern Industrial Growth." Samuel Insull, Esq.

A special meeting conducted jointly by the Institute and the Philadelphia Section of the Illuminating Engineering Society was held on Friday evening, March 19, 1915. Two papers were presented, one by Dr. Herbert E. Ives and E. F. Kingsbury, entitled "Method of Securing Uniformity of Readings on the Flicker Photometer with Different Observers," and another by Professor John Hammond Smith, of the University of Pittsburgh, on "Photo-sculpturing."

Dr. W. F. M. Goss, who was originally scheduled to address the meeting of April 21, was unable to be present, and Dr. Edwin F. Northrup, who had been announced to present a paper before the sections, was invited to address the meeting.

Nearly all the above papers have since appeared in the Journal.

Respectfully submitted,

James S. Rogers,
Chairman.

Philadelphia, January 12, 1916.

REPORT OF THE COMMITTEE ON INSTRUCTION

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

The courses offered in the ninety-first year of the Institute's School of Mechanic Arts, commencing in September, 1914, were substantially the same as those given in the preceding year, and the division of the instructional work into the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture was maintained.

The School opened on September 14, 1914, and during the year two hundred and sixty-seven students enrolled. This represented a decrease of fifty-three from the preceding year, and, judging from the number of requests for deferred payment of fee, was probably due to the prevailing industrial conditions. The largest classes formed during the year were those in Drawing and Mathematics.

The faculty for the year was as follows:

Professor William H. Thorne, Director of the School, and in charge of the Department of Drawing.

Professor William E. Bullock, Assistant Director, and in charge of the Department of Mechanics.

Professor Simeon van T. Jester, in charge of the Department of Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

Professor Thorne was assisted in his Department by Professor Clement Remington, in charge of Architectural and Freehand Drawing, and by Messrs. F. H. Lobb, I. P. Pedrick, C. Rommel, and W. W. Twining, instructing in Mechanical Drawing.

Mr. H. S. Detwiler assisted in the Department of Mathematics, and Messrs. E. Bark and M. M. Mark in Mechanics.

The attendance in the School throughout the year was well above the average, and exceptionally good work was done in all departments.

During the year students of the School, accompanied by instructors, visited the following places of interest:

Millbourne Mills, Sixty-third and Market Streets, Philadelphia, Pa.

Otto Gas Engine Works, Thirty-third and Walnut Streets, Philadelphia, Pa.

Curtis Publishing Company, Independence Square, Philadelphia, Pa.

Beach Power House, Philadelphia Rapid Transit Company, Beach and Laurel Streets, Philadelphia, Pa.

Link Belt Company, Hunting Park Avenue, Philadelphia, Pa.

Engineering Building, University of Pennsylvania, Thirty-third and Walnut Streets, Philadelphia, Pa.

Bureau of Water, Queen Lane Pumping Station, Fairmount Park, Philadelphia, Pa.

In every case the attendance was good and much interest was shown by those present. Our thanks are due to the managements represented for their courtesy.

The graduating exercises were held in the Hall of the Institute on the

evening of April 16, 1915. Dr. Walton Clark, President of the Institute, occupied the chair, and the graduating address was delivered by Dr. George A. Hoadley, Professor Emeritus of Physics, Swarthmore College, Swarthmore, Pa. The Alumni Association was represented by Mr. John F. Abbott. The annual report of the work of the School was presented by Professor Thorne. Sixty-one students were graduated: thirty-one in Mechanical Drawing, three in Architectural Drawing, two in Freehand Drawing, eighteen in Mathematics, four in Mechanics, and three in Naval Architecture. Three students in the Department of Drawing, one in the Department of Mathematics, and one in the Department of Mechanics were the recipients of the Edmonds Scholarships. Twelve students in the Department of Drawing were the recipients of scholarships from the B. H. Bartol Fund entitling them to free instruction. Six students were awarded free scholarships from the Isaac B. Thorn Fund. The student in the Department of Drawing having the best set of drawings for the year was awarded a prize donated by Mr. W. D. Baldwin, President of the Otis Elevator Company. The student of greatest merit in the Department of Mathematics was awarded a prize donated by Mr. J. B. McCall, President of The Philadelphia Electric Company. Two Prizes in the Department of Mechanics were awarded to students of greatest merit, one by Mr. Wilfred Lewis, President of the Tabor Manufacturing Company, and the other by Mr. S. M. Vauclain, Vice-president of The Baldwin Locomotive Works. A set of drawing instruments, offered by the New York Shipbuilding Company, was awarded to the student of greatest merit in the Department of Naval Architecture. Six graduates received awards provided by the Alumni Association of The Franklin Institute, and ten graduates making a perfect attendance record were awarded free membership for one year in the Association. In the Winter Term thirty-five students were awarded certificates of Honorable Mention; forty-seven students received similar certificates in the Spring Term.

The registration figures for the year, as well as for the previous year for comparison, follow:

	1913–14		1914–15	
	Winter Term Sept.–Dec.	Spring Term Jan.–Apr.	Winter Term Sept.–Dec.	Spring Term Jan.–Apr.
Drawing	188	148	154	125
Mathematics	71	57	70	51
Mechanics	30	28	30	22
Naval Architecture	17	15	4	4
	306	248	258	202

A lecture, entitled "West Indies and the Spanish Main," was delivered in the Hall of the Institute, by Mr. Frederick Monsen, F. R. G. S., on January 15, 1915, under the auspices of the Alumni Association, to which all the students were invited.

The graduates were invited to the annual smoker and luncheon of the Alumni Association, held on the evening of Saturday, April 10, 1915. At the luncheon 124 covers were laid, and speeches were made by Mr. L. E. Levy, Professor Thorne, and Mr. Abbott.

During the summer the School Calendar was published and all prepara tions made for the ninety-second session. Valuable prizes were again donated

by Mr. S. M. Vauclain, Mr. W. D. Baldwin, Mr. J. B. McCall, Mr. Wilfred Lewis, the New York Shipbuilding Company, and the Alumni Association.

A schedule of visits to engineering establishments was arranged.

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

During the fiscal year ending September 30, 1915, there were fifty-five members enrolled; resignations were received and accepted from fifty-nine members; and deaths were recorded of twenty-eight members.

The figures for the several classes of membership and for the two preceding years follow:

	1912–13	1913–14	1914–15
ELECTIONS:			
Resident Members	101	47	25
Non-Resident Members	186	57	24
Associate Members	1	7	2
Honorary Members	0	0	0
Life Members	3	0	4
	291	111	55
RESIGNATIONS:			
Resident Members	16	17	30
Non-Resident Members	13	12	25
Associate Members	2	2	3
Second Class Stock			1
	31	31	59
DEATHS:			
Resident Members	8	6	9
Non-Resident Members	4	4	8
Life Members	6	14	9
Honorary Members	1	2	0
Associate Members	0	0	0
Second Class Stock			2
	19	26	28
SUMMARY:			
Total Elections	291	111	55
Total Resignations	31	31	59
Total Deaths	19	26	28

Net decrease in membership 32

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE FOR THE YEAR 1915.

FINANCIAL STATEMENT, OCTOBER 1, 1914, TO SEPTEMBER 30, 1915.

Property and Funds.

Building and land, 13–17 South Seventh Street		$60,000.00	
Library		100,000.00	
			$160,000.00
	Principal	Income	Unexpended
Funds held by Board of Trustees	$280,859.14	$514.02	
Funds held by Board of Managers	17,122.45	34.21 (overdrawn)	
Franklin Institute Building Fund	371,666.30		
Elliott Cresson Medal Fund	3,000.00	105.70	
Franklin Fund and Building Committee	4,483.36		
Total funds	$683,494.75	$585.51	684,080.26
Grand total			$844,080.26

Liabilities.

Certificates of Stock	$29,870.00
Mortgage on Institute Building (held by Trustees as investment for funds)	30,000.00
Bills payable	27,250.00
Accounts payable	4,543.97
Unearned income	1,117.75
Edmonds Scholarship donation	50.00
Grand total	$92,831.72

Income and Expenses Applicable to Year Ending September 30.

Income.

Dues		$10,598.53
Initiation fees		110.00
General Endowment Fund		10,008.62
James H. Cresson Memorial Fund		2,267.92
John Scott Medal Fund		900.00
Estate of John Turner		124.97
Estate of Robert Wright		1,885.82
Instruction: Drawing	$1,370.00	
Mathematics	600.00	
Mechanics	260.00	
Naval Architecture	50.00	
		2,280.00
Publications: Subscriptions and Sales	$1,956.36	
Advertising	2,411.47	
		4,367.83
Total		$32,543.69

Expenses.

Building: Wages	$1,211.75	
Repairs and maintenance	649.86	
Taxes, water rent and insurance	548.19	
Heat, light, and power	662.46	
Miscellaneous supplies and expense	264.50	
		$3,336.76
Elections and resignations		171.48
Instruction: Drawing	$1,096.00	
Mathematics	333.00	
Mechanics	312.50	
Naval Architecture	172.00	
Miscellaneous Expense	1,158.27	
Popular Lectures	69.75	
		3,141.52
Library: Salaries	$4,612.02	
Books and periodicals	1,626.25	
Binding	785.40	
Miscellaneous expense	209.09	
		7,232.76
Meetings		772.56
Office and General: Salaries	$8,384.09	
Office expense	770.94	
General expense	1,405.00	
		10,560.03
Publications: Printing	$5,729.95	
Reprints	685.44	
Illustrating	695.38	
Miscellaneous expense	658.30	
Year-Book	500.00	
		8,269.07
Science and Arts		1,584.76
Sections		1,076.15
Basement renovation		380.46
Interest and discount		1,876.76
Membership badges		20.05
Miscellaneous income and expense		191.10
Total		$38,613.55
Deficit		$6,069.86

During the fiscal year the only important change in any of the Institute's funds has been an increase, through income, of The Franklin Institute Building Fund of $7741.99. There has been an increase in bills payable of $7000.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON PUBLICATIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

In the closing month of the past year the Institute completed the publication of the 180th volume of its Journal of Science and the Mechanic Arts, and the 90th year's record of its Transactions. A review of these publications and of their significance as milestones marking the advances of Science and the Arts during these nine decades may well be left for the time ten years hence, when the Journal of The Franklin Institute will have completed a full century's record of progress in the field of its activity, but at the present juncture it may be no less proper to point to the issues of the past year as evidences of the increasing scope of that activity. More than ever before the Journal of the Institute has become a record not only of the advances made in the field of the applied sciences, but also of researches which open the way to further progress. The field widens from day to day, and the volumes of our record thicken from year to year.

In keeping up this record your Committee has endeavored to coöperate to the fullest possible extent with the Editor of the Journal and with the Board of Associate Editors, to whose collaboration in this respect the Institute is largely indebted. A welcome addition to this Board has recently been afforded us through the adhesion of Dr. A. S. Eve, Professor of Physics at McGill University in Montreal. Your Committee has also the satisfaction of reporting that the Notes of Research Work from the U. S. Bureau of Standards, which have been published in the Journal throughout the past year, have latterly been supplemented by those of the Nela Research Laboratory of the National Electric Light Association, and also by similar communications from the Research Laboratory of the General Electric Company and from that of the Eastman Kodak Company.

The Year-Book of the Institute, revised to the end of our last fiscal year and amplified by the reports of the President of the Institute and of its various standing Committees, was published in due course last October. The edition was materially increased to permit of its being distributed among scientific institutions and technical societies at home and abroad as a means of increased publicity for the Institute in general and also in furtherance of the Membership Campaign latterly undertaken and now in progress.

The expense of publishing the Journal and the Year-Book during the past fiscal year, including reprints furnished to authors of articles printed in the Journal, was $8269.07. The income from subscriptions and sales of the Journal and of extra numbers of reprints was $1956.36, and from the Advertising Account $2411.47, leaving a balance of $3901.24 to be accounted as the cost of the Journal furnished to the individual members of the Institute.

Respectfully submitted,

Louis E. Levy,
Chairman.

Philadelphia, January 12, 1916.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers of The Franklin Institute:

During the year ending September 30, 1915, twenty lectures were delivered, as follows:

Section of Physics and Chemistry—*Five Meetings.*

October 1, 1914.

"The Ultra-violet Rays and Their Application for the Sterilization of Water." Max von Recklinghausen, Ph.D., The R. U. V. Company, Inc., New York City, N. Y.

November 5, 1914.

"Artistic Painting and the Secrets of the Old Masters." Maximilian Toch, Ph.D., Director of Research Laboratory, Toch Brothers, New York City, N. Y.

December 3, 1914.

"Modern Views on the Constitution of the Atom." A. S. Eve, D.Sc., Professor of Physics, McGill University, Montreal, Canada.

January 28, 1915.

"The Production of Light by Animals." Ulric Dahlgren, Ph.D., Professor of Biology, Princeton University, Princeton, N. J.

February 4, 1915.

"Moisture in Agricultural Products." C. L. Alsberg, Ph.D., Chief, Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C.

Mechanical and Engineering Section—*Five Meetings.*

November 12, 1914.

"Biochemical and Engineering Aspects of Sanitary Water Supplies." George W. Fuller, C.E., Consulting Hydraulic and Sanitary Engineer, New York City, N. Y.

December 10, 1914.

"The Modern Submarine in Naval Warfare." R. H. M. Robinson, Managing Director, Lake Torpedo Boat Company, Bridgeport, Conn.

January 7, 1915.

"The Organization, Character of Personnel, Scope of Work, and Methods of Operation and Control of a Large Municipal Highway Department." William H. Connell, Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

March 4, 1915.

"Hydraulic Works of the Panama Canal." Carleton E. Davis, Chief, Bureau of Water, Philadelphia, Pa.

April 8, 1915.

"Rapid Transit Problems in Philadelphia." H. H. Quimby, C.E., Chief Engineer, Department of City Transit, Philadelphia, Pa.

ELECTRICAL SECTION—*Three Meetings.*

February 11, 1915.

"Recent Researches in Electricity at the Bureau of Standards." E. B. Rosa, Ph.D., Chief Physicist, Bureau of Standards, Washington D. C. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

April 1, 1915.

"Modern Theories of Magnetism." George F. Stradling, Ph.D., Head of Science Department, Northeast High School, Philadelphia, Pa. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

April 15, 1915.

"Control and Protection of Electric Systems." Charles P. Steinmetz, M.A, Ph.D., Consulting Engineer, General Electric Company, Schenectady, N. Y. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

SECTION OF PHOTOGRAPHY AND MICROSCOPY—*Four Meetings.*

October 15, 1914.

"Recent Advances in Photographic Chemistry." Henry Leffmann, M.D., Ph.D., Philadelphia, Pa. (Joint meeting with Photographic Society of Philadelphia.)

October 28, 1914.

"Physics of the Photographic Process." C. E. K. Mees, D.Sc., Director of Research Laboratory, Eastman Kodak Company, Rochester, N. Y. (Joint meeting with Photographic Society of Philadelphia.)

February 25, 1915.

"Recent Progress in the Making of Photographs in Color." Henry Hess, M.E., Philadelphia, Pa. (Joint meeting with Photographic Society of Philadelphia.)

March 25, 1915.

"Recent Advances in the Technographic Arts." Louis Edward Levy, Photo-chemist, President, Graphic Arts Company, Philadelphia, Pa.

MINING AND METALLURGICAL SECTION—*Two Meetings.*

January 14, 1915.

"Modern Steels and Their Heat Treatment." R. R. Abbott, B.S., M.E., Metallurgical Engineer, The Peerless Motor Car Company, Cleveland, Ohio. (Joint meeting with American Society of Mechanical Engineers.)

October 8, 1914.

"Recent Developments in Cast Iron Manufacture." J. E. Johnson, Jr., Consulting Engineer and Metallurgist, New York City, N. Y. (Joint meeting with American Society of Mechanical Engineers.)

One special meeting of the Sections and the Philadelphia Chapter of the American Institute of Architects was held on Friday evening, October 30, 1914. A paper was presented by Dr. Wallace C. Sabine, Dean of the Graduate School of Applied Science, Harvard University, Cambridge, Mass., on "Architectural Acoustics."

Nine joint meetings were held, one with the Philadelphia Chapter, American Institute of Architects; two with the American Society of Mechanical Engineers; three with the Philadelphia Section, American Institute of Electrical Engineers, and three with the Photographic Society of Philadelphia.

Lantern slides, special apparatus, and exhibits were used to illustrate the lectures. The greater number of papers were referred to the Committee on Publications for publication in the JOURNAL.

The attendance at the meetings still continues to increase; on three occasions the hall was taxed beyond its capacity.

Respectfully submitted,

CHARLES DAY,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON ENDOWMENT

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

Your Committee begs leave to make the following report:

During the past year an effort was made to secure additional subscriptions to meet the terms of the bequest of Dr. Wahl to The Franklin Institute, in which the Institute was named residuary legatee at the death of Mrs. Wahl on condition that an amount equal to that of the estate be subscribed within three years after Mrs. Wahl's death. The time will expire December 16, 1916. The value of the estate is approximately Eighty-five Thousand Dollars ($85,000). Subscriptions have been received amounting to Twenty-five Thousand, One Hundred and Fourteen Dollars ($25,114). During the coming year we must obtain subscriptions amounting to, at least, Sixty-five Thousand Dollars ($65,000).

May we ask that every member make a prompt and liberal subscription to this fund. We do not wish to limit the subscriptions to Members of the Institute, and will be glad to receive subscriptions from all who are interested in the promotion of the Mechanic Arts.

The Wahl Bequest to The Franklin Institute and the like sum subscribed will enable the Franklin Fund and Building Committee to at once take steps

to erect a suitable building on the site owned by the Institute at the southeast corner of Nineteenth and Race Streets.

During the past year the estate of Elizabeth Shippen has been settled. The Franklin Institute was one of the six residuary legatees. The Institute's proportion of the residuary estate is as follows:

Principal	$158,068.89
Accumulated interest	17,875.87

The principal, as soon as it is received, will be transferred to the Board of Trustees of the Institute for investment.

Respectfully submitted,

Henry Howson,
Chairman.

Philadelphia, January 12, 1916.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

Your Committee on Science and the Arts has the honor to submit the following account of its activities for the year ending September 30, 1915.

At the April meeting Mr. William Chattin Wetherill was elected to serve on the Committee, to fill the unexpired term of Mr. Tinius Olsen, who removed from the city.

The resignation of Mr. William E. Bullock, Science and Arts Assistant, was announced at the June meeting.

Mr. T. R. Parrish was appointed, September 1, to fill the vacancy left by Mr. Bullock.

At the September meeting the following resolution was adopted on the occasion of the death of Richard Gilpin, member of the Committee:

> "The Committee on Science and the Arts of The Franklin Institute, sensible of the loss its membership has sustained through the untimely death of Richard Gilpin, on June 21, unanimously resolves that there be recorded in its minutes this present memorial of the faithful service rendered by Richard Gilpin as member of this body during the past eleven years, in recognition of his efficient collaboration as a technologist, and in appreciation of the sterling qualities of his genial personality. The Committee further resolves that this minute be published in the Journal of the Institute, and that an engrossed copy thereof be transmitted to the family of the deceased."

The Committee investigated and disposed of thirty cases during the year.

The average attendance at the stated meetings was 20.3, or 33 per cent. above the quorum necessary for all action on reports. At no meetings was the attendance less than seventeen.

The Sub-committee on New Subjects and Preliminary Examination held one meeting before each stated meeting of the Committee. During the year it

considered seventy-one subjects and recommended nineteen for examination. Sixteen applications for investigation resulted from such recommendations.

In accordance with the recommendation of the Sub-committee on New Subjects and Preliminary Examination, a blank card, on which might be suggested new subjects for examination, was sent to each member of the Committee with the notice of each stated meeting. Fifteen subjects were suggested by means of these cards.

Appended to this report is a detailed statement of the operation of the Committee during the year. The number of awards recommended by standing sub-committees and sub-committees of investigation is as follows:

SUB-COMMITTEE ON THE FRANKLIN MEDAL.

Number of awards 2

SUB-COMMITTEE ON LITERATURE.

Number of Potts Medals recommended 1
Number of Longstreth Medals recommended 4

SUB-COMMITTEES ON APPLICATIONS FOR INVESTIGATION.

Number of awards recommended 14

Your Committee has continued the practice of having an informal dinner prior to each meeting. The average attendance at these dinners was twelve.

During the year many of the inventors and investigators whose work was favorably recommended by your Committee were present at the stated meetings of the Institute and received in person the medals awarded them. The Chairman made brief statements relative to the work of each, and introduced them to the President, who made the presentations on behalf of the Institute.

Efforts have been made to extend the knowledge of the work of your Committee. Cards were printed giving a list of the awards at the Institute's disposal, or made on its recommendation, together with the conditions under which the awards are made, and sent to engineering, scientific, and educational bodies. The work of the Committee was also brought to the attention of the officers of the Panama-Pacific Exposition, in San Francisco, Cal.

The Franklin Medal Fund, founded by Mr. Samuel Insull, of Chicago, Ill., and the award of the medals to Thomas Alva Edison, of Orange, N. J., and Prof. Heike Kamerlingh Onnes, of Leiden, Holland, have done much to further bring the activities of the Institute to the attention of the lay as well as the scientific world.

The work of the past year was of exceptional interest, and the investigations made by the sub-committees, as well as the other work of the Committee, was carefully and thoroughly done.

Respectfully submitted,

G. H. Clamer,
Chairman.

Philadelphia, January 12, 1916.

APPENDIX.

STATEMENT OF THE COMMITTEE'S OPERATION FOR THE YEAR ENDED SEPTEMBER 30, 1915.

CASES.

Cases pending, October 1, 1914		18
Applications during the year	16	
Special reports	7	
		— 23
		41
Disposed of during the year		30
Leaving pending		11

DISPOSITION OF CASES.

Franklin Medal Awards	2
Elliott Cresson Awards	1
Howard N. Potts Awards	1
Edward Longstreth Awards	7
John Scott Legacy Recommendations	8
Certificates of Merit	2
	21

AWARDS MADE DURING THE YEAR.

THE FRANKLIN MEDAL.

Thomas Alva Edison, of Orange, N. J., in recognition of the value of numerous basic inventions and discoveries forming the foundation of world-wide industries, signally contributing to the well-being, comfort, and pleasure of the human race.

Prof. Heike Kamerlingh Onnes, of Leiden, Holland, in recognition of his long-continued and indefatigable labors in low-temperature research which have enriched physical science, not only with a great number of new methods and ingenious devices but also with achievements and discoveries of the first magnitude.

THE ELLIOTT CRESSON MEDAL.

Michael J. Owens, of Toledo, Ohio, for his Automatic Bottle Machine.

THE HOWARD N. POTTS MEDAL.

William J. Humphreys, C.E., Ph.D., of Washington, D. C., for his paper on "The Thunderstorm and its Phenomena," in the November and December, 1914, issues of the JOURNAL.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Cav. Ing. Alberto Cerasoli, of Rome, Italy, for the Humphrey Pump.

Harold N. Anderson, of Cleveland, Ohio, for his Gear Rolling Machines.

Hyman Eli Goldberg, of Chicago, Ill., for the Wahl Calculating Attachment for Typewriters.

H. W. Hardinge, of New York, N. Y., for his Conical Pebble Mill.

Herbert Alfred Humphrey, of London, England, for the Humphrey Pump.

A. Atwater Kent, of Rosemont, Pa., for his Unisparker.

Elmer A. Sperry, of New York, N. Y., for his Gyro-Compass.

John C. Wahl, of Chicago, Ill., for the Wahl Calculating Attachment for Typewriters.

THE EDWARD LONGSTRETH MEDAL.

Edward J. Dobbins, of London, England, for his Daylight Rods.

Herbert E. Ives, Ph.D., of Philadelphia, Pa., for his paper on "Artificial Daylight," in the May, 1914, issue of the JOURNAL.

Max von Recklinghausen, Ph.D., of New York City, N. Y., for his paper on "The Ultra-violet Rays and Their Application for the Sterilization of Water," in the December, 1914, issue of the JOURNAL.

C. C. Tutwiler, A.B., M.S., of Philadelphia, Pa., for his paper on "The Recovery of Gas Works By-products," in the October, 1914, issue of the JOURNAL.

Wahl Adding Machine Company, of Chicago, Ill., for the Development of the Means for Manufacturing the Wahl Calculating Attachment for Typewriters.

George A. Wheeler, deceased, of Brooklyn, N. Y., for his Escalator.

C. D. Young, of Altoona, Pa., for his paper on "Locomotive Superheaters and Their Performance," in the July and August, 1914, issues of the JOURNAL.

THE CERTIFICATE OF MERIT.

W. A. Blonck, of Chicago, Ill., for his Blonck Boiler Efficiency Meter.

George P. Vanier, of Steelton, Pa., for his Potash Bulb.

JOHN SCOTT MEDAL RECOMMENDATIONS.
(Awards pending, September 30, 1915.)

Hans Hanson, of Hartford, Conn., for his invention embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

Frederick A. Hart, of New York City, N. Y., for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

Clement F. Street, of New York City, N. Y., for his Street Locomotive Stoker.

THE EDWARD LONGSTRETH MEDAL.
(Award pending, September 30, 1915.)

John Underwood and Company, of Hartford, Conn., for the development of methods and means for the manufacture of the Combined Typewriting and Calculating Machine.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, January 5, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 5, 1916.

MR. L. E. LEVY, *Chairman pro tem.*

The following report was presented for first reading:

No. 2634.—Cement-Gun.

Mr. John V. N. Dorr, of New York City, N. Y., described his Hydrometallurgical Apparatus.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 6, 1916, at 8 o'clock P.M., with Dr. Walton Clark in the chair. The minutes of the previous meeting were read and approved.

Fred H. Wagner, M.E., Chief Engineer of the Bartlett Hayward Company, Baltimore, Md., delivered an illustrated lecture on "Coal Gas Residuals." A description was given of the various methods employed in the by-product coke industry for the recovery, separation, and purification of ammonia and its salts, tar, benzol, toluol, naphthalene, phenol, cresol, and cyanogen. The procedures for the manufacture of dyes, synthetic drugs, chemical reagents, and explosives from the raw material were outlined. A vote of thanks was extended to the lecturer and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, January 12, 1916.*)

RESIDENT.

MR. H. W. BIDDLE, stock broker, 424 Chestnut Street, Philadelphia, Pa.

MR. WILSON CATHERWOOD, merchant, 1708 Walnut Street, Philadelphia, Pa.

MR. J. H. CUMMINGS, President, John B. Stetson Company, Philadelphia, Pa.

MR. FRANKLIN C. GURLEY, chemist, Benzol Products Company, Marcus Hook, Pa.

MR. ROBERT B. LEWIS, Mechanical Engineer, 4611 Wayne Avenue, Philadelphia, Pa.

MR. THORSTEN Y. OLSEN, Vice-President and Treasurer, Tinius Olsen Testing Machine Company, 500 North Twelfth Street, Philadelphia, Pa.

NON-RESIDENT.

MR. R. H. BALLARD, Secretary and Assistant Engineer, Southern California Edison Company, Edison Building, Los Angeles, Cal.

MR. T. E. CLARKE, Assistant to President, The Delaware, Lackawanna and Western Railroad Company, Scranton, Pa.

REV. JOSEPH A. CORCORAN, M.D., S.J., Professor of Chemistry, Loyola College, Montreal, Quebec.

MR. D. F. CRAWFORD, General Superintendent of Motive Power, Pennsylvania Lines West of Pittsburgh, Pennsylvania Station, Pittsburgh, Pa.

MR. OLIVER C. CROMWELL, Mechanical Engineer, Baltimore and Ohio Railroad Company, Mt. Clare, Baltimore, Md.

MR. GEORGE H. EMERSON, General Manager, Great Northern Railway Company, St. Paul, Minn.

MR. W. H. FINLEY, Chief Engineer, Chicago and Northwestern Railway Company, Chicago, Ill.

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A Practicable Example of Air-cooling. ANON. (*The Autocar,* vol. xxxv, No. 1053, December 25, 1915.)—The one and only representative of the air-cooled engine in the motor world sold as an every-day product is the Franklin. The car is not known except by name in Europe, but it has been for many years a standard product in the United States, and a very high standard of performance has been achieved. Its last record has just been completed under the official observation of the Automobile Club of America, and on this occasion the consumption of lubricating oil was carefully tested and was found to work out at 1046 miles per gallon. While this is far from being a record in low consumption, it is more than sufficient to show that the engine is by no means extravagant in the consumption of lubricating oil. A complaint frequently brought against the air-cooled engine is that of enormous oil consumption, extremists maintaining that, although water is dispensed with, so much lubricating oil is used that the engine might be called an oil-cooled rather than a water-cooled motor. The Franklin car upon which the particular tests were made is five-seated with closed body.

Only the bare results are at present available, but the engine is by no means a diminutive one, having six cylinders 90×102 mm. The car is very light, special attention having been given to the reduction of weight. The cylinder flanges are vertical, and a hood with open ends is placed over the engine. Vanes in the fly-wheel pull a current of air through the hood which conveys the heat from the flanges backward out of the bonnet. As the sole representative of the air-cooled motor car it is a most interesting machine, and its latest performance certainly disposes of the reproach as to excessive oil consumption.

CURRENT TOPICS.

Benzol Production at Coke Plants. Anon. (*U. S. Geological Press Survey Bulletin* No. 254.)—In response to the unprecedented demand for high explosives a new industry, the recovery of benzol and toluol, suddenly sprang into existence in the United States in 1915. Benzol and toluol, indispensable raw materials from which explosives, dyestuffs, and other chemical products are manufactured, are oils similar to gasoline in appearance and smell and are present in the gas that is driven off from coal when it is made into coke. Before the European war the demand in the United States for these products was so small and the price so low that but one company engaged in coke making sought to recover them on a large scale. Late in 1914 the price of benzol, and particularly toluol, rose to such a point that many other companies began to build plants to recover these oils, which were then being burned with the gas, and by the end of 1915 there were 19 new plants for benzol recovery in operation and others in course of erection.

Reports made to C. E. Lesher, of the United States Geological Survey, by all of the by-product coke plants in the country, indicate that the output of benzol and other light oils in 1915 amounted to 13,942,763 gallons, in connection with which there were produced 761,256 pounds of naphthaline, a solid crystalline substance. Some of the benzol-recovery plants, which consist essentially of a complicated system of absorption towers, pumps, stills, and storage reservoirs, were in operation at the beginning of the year, but many were built during the early months of 1915 under contracts calling for great speed in erection. Several of the plants are not equipped to separate the different oils found in the crude, and 7,322,670 gallons, more than half of the total output, was reported as crude benzol and light oil and was shipped in tank cars to refineries connected with powder works and other chemical industries. In the 6,620,093 gallons of oils refined at the place of recovery, there were 4,833,939 gallons of 100 per cent. benzol, 1,315,727 gallons of toluol, and 470,425 gallons of solvent naphtha.

Thirty-one coke-making establishments with 4933 by-product ovens contributed to this total, and it is estimated that between 8,000,000 and 9,000,000 tons of coal were carbonized in the ovens that furnished the gas from which the oils were recovered. The annual capacity of the benzol-recovery plants now in operation is estimated at over 20,000,000 gallons, and with the completion of plants now building will probably exceed 22,000,000 gallons. The

value of these products is indicated by the prices currently reported during the year. Benzol, normally selling for 20 cents or less a gallon, in September brought as high as $1.25 for immediate shipment and 65 cents on contract; toluol, with a normal price of 25 cents, was sold for as much as $6 a gallon for immediate delivery and was contracted for at $4.25 per gallon.

Benzol is an excellent motor fuel. The United States, whose output of gasoline is estimated in 1914 at 30,000,000 to 50,000,000 barrels (1,500,000,000 to 2,500,000,000 gallons), stands in no need of additional supplies for this purpose. There is, however, in the United States in normal times a large use for dyes and chemicals, such as carbolic acid, which depend upon benzol and toluol for raw material and which have in the past been largely imported from Germany either as finished or as intermediate products.

After the war demand for explosives is over and the price of benzol returns to normal, serious effort will, of course, be made to find a market for this product. Shut off from European competition, the dye and chemical industry in the United States is now making rapid strides forward. If this industry after the close of the war is able to hold its own against the highly-developed foreign competition it may completely absorb the output of benzol and add another source of income to the coke-oven plants.

The Life and Relining of Guns. L. CRESAP. (*The Iron Age*, vol. 97, No. 1, January 6, 1916.)—The life of a gun is measured by the number of rounds fired beyond which the erosion of the bore impairs the accuracy of fire beyond permissible limits. Erosion is produced by the action of the gases at high temperature and pressure. While the time element is small, yet the gun, of course, absorbs heat. This absorption is confined to a thin film of steel on the interior surface. The local heating causes the film to expand, and, there being no room to expand naturally, due to the cooler and thicker wall, the elastic limit is passed and permanent set takes place. Upon the release of the pressure, and in consequence temperature, contraction of the film occurs, and, as it has been crushed, this contraction causes minute cracks. This process continues, the minute cracks getting larger at each discharge. As they enlarge they form by-passes for the hot gas, which tends to further enlarge them. The process continues until the inner surface gets badly roughened and the lands begin to be eaten away. Finally the bore gets so enlarged that the gases can escape, the shell does not attain its proper rotation, and the flight of the shell becomes erratic and subject to errors; when the gun no longer maintains a reasonable accuracy and it is said to be worn out.

All guns except small ones are now constructed with liners in the tube, which, when the bore is worn out, are removed and replaced with new liners. The cost of thus relining a gun can be roughly fixed at 30 per cent. of the cost of the gun. There appears

to be no limit to the number of times that a gun can be relined; hence the life of a gun is indeterminate. It is, of course, a matter of arbitrary decision as to when a gun should be relined, as the criterion depends solely on what is considered as the accuracy desirable. It is difficult to generalize on the subject. The small arms used in this country are considered to be worn out after 5000 to 7500 rounds have been fired. Small naval guns have been fired about 1000 times before they were regarded as worn out. Large 12-inch and 14-inch naval guns are considered to have a life on one liner of from 150 to 200 rounds. Low-velocity guns, such as howitzers and mortars, have correspondingly longer life than high-velocity guns of the same calibre, because the pressures they use, and hence the temperatures, are lower.

As is seen from the preceding, the power and life of guns are functions of each other. The amount of power that can be wisely sacrificed for the sake of preserving the gun is not only extremely difficult to decide, but depends on many factors, some of which are subject to national policy. Taken broadly, calibre for calibre, permanent fortification artillery can be given the greatest power, naval artillery can be given almost as great power, and field artillery only moderate power.

The Cylinder Cooling of Internal Combustion Engines. F. W. LANCHESTER. (*Proceedings of The Institution of Automobile Engineers* (London), December, 1915.)—Every problem concerning the automobile, whether it be on land, air, or water, is essentially a problem of weight saving. The heat escaping from the working fluid to the cylinder walls has to be disposed of externally, either to air or water, whichever happens to be the most readily available. It is perhaps almost unnecessary to point out that water cooling, when used on automobiles and aëronautical machines, is in reality indirect air cooling, inasmuch as the water merely acts as a carrier of heat between the cylinder walls and the cooler or so-called radiator. Thus the underlying principles of radiator design, so far as they relate to air passages and cooling surface, are identical with those involved in the design of the ribbed jacket in the direct air-cooled engine.

The importance of weight saving, great as it is in ship building and railway work, still greater as it is in the design of the road automobile or motor car, becomes paramount in the flying machine or aëroplane. The cooling question, therefore, as applied to the road automobile and the flying machine, is one that must be considered essentially from the point of view of weight and weight saving.

The horse-power equivalent of heat dissipated in a gas engine is approximately equal to the actual horse-power of the motor. For motor-car work, the weight per horse-power of the water-cooling surface and complement of water is approximately 2½ pounds, apart

from the weight of jackets, pipes, pump, and their water content. When all incidentals are included, scarcely less than 3 pounds per horse-power can be attained in the road automobile or 1 pound per horse-power in the flying machine.

In comparison with the radiator water-cooling system, direct air cooling by means of ribs on the cylinder is subject to the serious limitation that the weight of such a system increases rapidly with the diameter of the cylinder. In fact, with cylinders above 300 mm. in diameter this system offers no advantages on the score of weight over the radiator system, but for such diameters as are currently employed for aëronautical work there appears from analysis to be a clear saving of three-quarters of a pound per horse-power.

The author is inclined to believe that radial ribs arranged lengthwise about the cylinder, provided with the necessary flow of air, offer the best solution of the problem of cooling, the direction of flow taking place from the open end of the cylinder towards the combustion space; that is to say, from the colder end towards the hotter.

Recent Vacuum Bottle Developments. ANON. (*Scientific American,* vol. cxiii, No. 26, December 25, 1915.)—The invention of the glass vacuum bottle is generally attributed to Professor Dewar, who produced it for the purposes of a container for liquefied gases. The Dewar flask consists of two glass bottles joined at the top of the neck but touching each other at no other place, the wall surface of the space between the inner and outer bottles being silvered. The space is then highly exhausted by means of a vacuum pump.

These flasks proving too fragile for other than laboratory purposes, Professor Reinhold Burger strengthened the device by inserting between the two walls little spaces or supports and enclosing the whole in an outer protecting metal shell. This improved article found a ready market as a conveyor and retainer of hot or cold liquids or foods. In spite of this improvement, however, the article was still comparatively fragile, leading to many attempts to produce these devices by using metal in the place of glass. It has remained for Mr. William Stanley, while engaged with other investigators—notably Dr. Irving Langmuir—in the study of heat insulation, to discover the cause of previous failures of the all-metal bottle and find a remedy.

A study of the action of gaseous molecules as heat carriers proved that the high insulation effect of the Dewar flask is coincident with the attainment of a very high vacuum at what might be called a critical point in the exhaustion, and rapidly increases as this already high vacuum is slightly improved. This "critical point" for Dewar flasks was found to represent a degree of vacuum so high that the mean free path of the gaseous molecules was as great as the distance between the outer and inner vacuum walls. Accepting the limitation of the lower degree of vacuum obtainable in a metal container

by the presence of occluded gases at the surface, Mr. Stanley conceived the idea that if the vacuous walls could be brought so close together that the distance between them would be equivalent to the mean free path of the molecules at a comparatively poor degree of exhaustion, a "critical point" condition could be so obtained. He accomplished this result, not by spacing an outer and inner wall extremely close together, but by filling the vacuous space with very finely divided material, itself so chosen as to be incapable of giving off or absorbing gas in a vacuum. Vessels constructed on this principle fully confirmed Mr. Stanley's conclusions, and a commercially practical vacuum bottle without the use of glass was evolved.

Museum Fatigue. B. I. GILMAN. (*The Scientific Monthly,* vol. 2, No. 1, January, 1916.)—"Museum fatigue" is an accepted evil, hitherto tacitly recognized as admitting only relief. May not a study of how it comes about suggest some means of its prevention? The plan adopted in the inquiry consisted in devising a series of simple questions relating to certain objects, mostly installed at higher or lower levels and in cases; and an observer was photographed in the act of answering them. The museum in which the photographs were taken no longer exists, but the conditions depicted are still well-nigh universal.

The pictures obtained indicate that an inordinate amount of physical effort is demanded of the visitor by the present methods in which we offer most objects to his inspection. It is at once evident that these methods form an effective bar to the adequate fulfilment by museums of the public function they aim to perform. Not even the hardiest sight-seer will long go through the contortions which the pictures indicate are needed for any comprehension of much of what we display to him. After a brief initial exertion he will resign himself to seeing practically everything imperfectly and by a passing glance. If the public is to gain more than a minute fraction of the good from museum exhibits which is theirs to give and can now be gained by the private student, radical changes in our method of exhibition are imperative. As at present installed the contents of our museums are in large part only preserved, not shown.

The Rubber Industry. A. H. KING. (*Metallurgical and Chemical Engineering,* vol. xiv, No. 1, January 1, 1916.)—No material has yet been found that combines such a degree of strength, elasticity, and wearing power as rubber. These properties make rubber especially valuable in manufacturing the various grades of hose for air, water, steam, and oil; belts; valves and other moulded articles, and tires of all kinds. A complete list of all the various things made of rubber would be almost infinite.

The first mention of this remarkable substance from a European was by Christopher Columbus, who on his second voyage of discovery (1493–1496) saw the natives of Haiti playing with balls which

he afterward learned were prepared from the gum of a tree. This gum they called cahuchu, from which the word caoutchouc is derived. Highly interesting must this gum have been to the Spaniards. By it they were able, in a crude manner, to waterproof their garments and thus protect themselves from the heavy tropical rains. They also made the acquaintance of the related substance, balata. They found shieltls made of balata-impregnated cloth. The same material was used in the preparation of suits which resisted poisoned arrows. In fact, such suits are now to be seen in the Spanish Museum at Madrid. This was indeed a fine forerunner of the modern balata belt.

The English word for rubber was given it by Priestley in 1770, who recommended its use for removing pencil-marks. This would likely have remained its principal use had not the discovery of vulcanization been made. Raw rubber is not suitable for proofing garments, due to the narrow range of temperature within which it is elastic but not sticky. Below 10° C. it begins to become hard, and at 0° C. it is brittle. However, it regains its former properties on warming. Above 25° C. it has a great tendency to become sticky, and if heated above 75° C. it becomes permanently tacky.

The beginning of the rubber industry dates from the discovery, in 1839, of the important process of vulcanization by Nelson Goodyear. The bicycle craze of some years ago gave it added impetus, and later the automobile. It is now an accepted fact that these machines cannot be comfortable without pneumatic tires. It has been estimated that at least 85 per cent. of all rubber used in manufacturing goes to tires and only 15 per cent. to mechanical goods. The United States alone uses about 100,000 tons of crude rubber per year.

Increased Arsenic Production. ANON. (*United States Geological Survey Press Bulletin,* No. 251, December 31, 1915.)—The year 1915 saw another increase in the output of white arsenic, and the estimated production for the twelve months is reported by the United States Geological Survey to have been 5195 tons (of 2000 pounds), with a value at the smelters of 2 cents a pound, or a total of $207,780. The estimate by Frank L. Hess is based on the known production for the first ten months of the year and the probable output during November and December. This output is an increase of more than 11 per cent. over the 1914 production and 65 per cent. over the 1913 output.

All white arsenic made in this country is a by-product in the smelting or refining of the non-ferrous metals, and naturally the larger part is saved at the western plants. The demand is far below the possible production, which could probably be made treble or quadruple the present output if prices were sufficiently encouraging.

The largest uses for arsenic are in the manufacture of insecticides, such as Paris green, lead arsenate, etc.; in glass making, and as a weed killer. Small quantities are used in shot, medicine, and dyes.

Commercial Lighting. E. M. COLQUHOUN. (*American Gas Light Journal*, vol. civ, No. 1, January 3, 1916.)—Commercial lighting embraces the lighting of stores, factories, churches, halls, and other places of a public or semi-public nature. It is in this field, since the introduction of electric lighting, that gas has met the most severe competition. In efficiency which leads to economy, gas has always successfully met electric competition, but the advantage of economy in operating costs, formerly so beneficial to the gas industry, does not exist to the same extent to-day.

In considering the comparative costs of illumination by gas and electricity, there must be taken into account the cost of gas or of electric energy, the efficiency of the units used, and the cost of their upkeep. A few years ago the average medium-sized store could be illuminated by three upright arc lamps at a cost of $76 per year, including gas and maintenance. The cost to illuminate such a store by electricity with carbon lamps was about $385. The inverted gas arc lamp made it possible to light a similar store for $55, compared with $95 using tungsten lamps. To-day, with the most efficient units available, the cost would be $51 for gas and $60 for electricity.

In these comparisons gas is figured at $1 per 1000 cubic feet, and electricity at 10 cents per kilowatt-hour; and, while it is true many companies are selling gas much lower than $1 per 1000, it must be recognized that electric companies have largely adopted the demand system of charging for current, and, though the base rate for a few hours' burning may be 10 cents per kilowatt-hour, the excess after one hour's average daily burning is secured at a much lower rate. For the average commercial installation this would mean that the low rate would be secured for the current used in excess of $3 per month, and in many instances much less than this amount. The newer lamps, with their lessened demand, will result in a still lower amount to which the base rate will be applicable. However, the costs of illumination with gas and electricity have been decreased principally by the increased efficiency of the lamps. To-day 32 candle-power is secured with one cubic foot of gas, as compared with 17 candle-power a few years ago. The increase in efficiency of the electric units has even exceeded that of the gas units, and it is now possible to secure 13 candle-power with a consumption of 10 watts, where a few years ago it was necessary to use 10 watts for 3 candle-power. These figures show that the advantage of low operating costs for gas has decreased materially.

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SMOKE AS A SOURCE OF ATMOSPHERIC POLLUTION.*

BY

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I. INTRODUCTION.

The presentation which follows is based upon investigations made in the city of Chicago during the past six years. The investigations have been the outgrowth of a popular belief that the atmosphere of Chicago has been more smoky than it needed to be, and that the steam locomotives of the Chicago railroads have been large contributors to the total smoke content of the atmosphere.

After much discussion in the City Council and elsewhere, the Chicago Association of Commerce, an organization devoted to the welfare of the city and in a peculiar sense representative of its business interests, undertook, in 1909, the direction of an educational movement in the abatement of smoke, and has since persisted in its efforts. It first appointed an expert committee to consider and report upon questions relating to the desirability and the practicability of electrifying the steam railway terminals of the city, and upon other questions relating to the elimination of smoke. This committee, in due time, presented a report containing a series of recommendations. Its conclusion with reference to the

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[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

electrification of railroads was to the effect that such electrification was practicable from an engineering standpoint; that when effected it would be of economic advantage to the railroads; that it would present no greater element of danger than now exists; and that the most serious and difficult features of the problem were financial.

The railroads declined to accept the conclusions set forth by this report, and in stating their objections they emphasized the fact that the conclusions of the committee were merely the opinions of individual members; that the committee had made no investigations and was in possession of no information not available to others.

This attitude on the part of the railroad officials emphasized the desirability of a thorough investigation, which should determine the relative responsibility of the different fuel-consuming services for the smoke of the city, and the practicability of electrifying its steam-railroad terminals as a means in smoke abatement. It was finally agreed that if the Association of Commerce would provide for the organization of such an investigation, the cost of conducting it would be met by the railroads of Chicago.

In obedience to this arrangement, a second committee was appointed, which has since been known as the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals. The committee thus formed, consisting of sixteen members, was organized for work in 1911. Four of its members were representatives of the city government and were nominated by the Mayor of the city of Chicago, four were railway presidents, and nine were representatives of the Association at large. Its purpose was early defined as follows:

1. To bring about a determination as to the necessity for changing the motive power of steam locomotives to electric or other power.

2. To determine the mechanical or technical feasibility of such a change.

3. To determine the financial practicability of such a change.

A chief engineer was appointed, and under his direction an expert staff was organized to conduct the necessary investigations. The work thus outlined has now been completed and the

report of the committee has been issued.[1] The methods employed by this committee in its investigations will be serviceable to those who may be called upon to investigate similar problems in other cities. Many of the conclusions which have been drawn may be accepted as of rather general application.

II. THE EFFECTS OF SMOKE AS THEY APPEAR IN LITERATURE.[2]

Smoke and soot are generally regarded as modern evils. They are not so in fact. Our first definite information of the use of bituminous coal is gained from complaints which were made against its use because of its smoke. In England, in the time of Edward the First, the nobility protested against the use of "sea-coal," and fifty years later a man is said to have been put to torture in London because he filled the air with a "pestilential odor" through his use of coal. In the middle of the fourteenth century the authorities of the German town of Zwickau proclaimed as law: "Know ye that all smiths working within the walls must refrain from the use of coal in their work." Toward the end of the eighteenth century many scientific and practical men, among whom are to be numbered the celebrated engineer, James Watt, and the distinguished and ever-active Benjamin Franklin, gave attention to problems arising in connection with the use of bituminous coal for domestic and industrial purposes.

In general, the prohibition of smoke ordinances relates to its visible aspect. Many American cities prohibit "dense smoke"; others, "black, thick, and continuous smoke"; and still others, "dense black or dense gray smoke." The city of Philadelphia attempts greater precision by specifying "smoke intercepting more than 60 per cent. of light, and fumes of sulphurous or noxious odor." Obviously, these terms are not precise. In many cases they have been found too elastic to sustain a proper enforcement of the ordinance. A comprehensive definition of smoke must take account of the process by which the smoke is produced, the

[1] "Smoke Abatement and Electrification of Railway Terminals in Chicago," a report of the Association of Commerce Committee of Investigation.

[2] Smoke as an element in the pollution of the atmosphere has been extensively studied. A list of articles consulted by the Chicago committee contains 450 entries.

nature and composition of its constituents, the manner in which this may be diffused in air, and the degree to which they may separately or collectively be regarded as injurious or objectionable.

The literature of the subject shows that the methods devised for studying the atmosphere of cities are still largely experimental. Although soot and its effects have formed the principal subjects of complaint, the methods commonly employed in determining the solid content of smoke-polluted air are admittedly less satisfactory than those used in determining the gaseous content. The fact is coming to be emphasized that effective smoke inspection must involve technical knowledge and the skilful use of laboratory equipment. Comparative studies of the air of neighboring cities based on such methods are being generally urged.

The influence of smoke in the atmosphere upon health constitutes a question which has been much discussed. The testimony as it appears in existing literature is conflicting. Doubtless many writers have been inclined to over-emphasize the effect of smoke upon health. A summary of such a review of this phase of the problem has been set forth as follows:[3]

> 1. There is a general agreement among sanitary authorities that polluted air is harmful to health.
>
> 2. At the present time there is no accurate method of measuring this harm, nor of determining the relative responsibility of the different elements which enter into the mixture of gases and solids commonly referred to as atmospheric air.
>
> 3. The direct effect of smoke or of any of its attributes, including soot, dust, and gases, in amounts which may ordinarily pervade the atmosphere of a smoky city, are not shown to be detrimental to persons in normal health.
>
> 4. The direct effect of smoke upon those who are ill has been most extensively studied in connection with tuberculosis and pneumonia. It appears that smoke does not in any way stimulate the onset of the tubercular process nor militate against the rapidity of recovery

[3] Report of the Chicago Committee of Investigation.

when once this disease has been contracted, but that it has a direct antiseptic effect and tends to localize the disorder. In cases of pneumonia the effect becomes seriously detrimental.

5. In addition to these direct results, indirect effects result from the diminution of sunlight and the increase in fogs, clouds, and haze.

The effect of smoke upon vegetation where the exposure is severe is clearly shown. The results of observations and experiments touching this phase of the matter have been summarized as follows:[4]

1. That smoke may exert injurious effects on vegetation. These effects may be direct or indirect. The direct effects are slow in asserting themselves, trees and plants exposed to them gradually losing vigor through a series of years until they finally perish.

2. That the products of combustion which are most pronounced in their direct effects are the soot and tar discharges and the sulphurous gases, though injury may occur as a result of an increased acidity in the soil caused by smoke.

3. That the indirect effects appear as a result of fogs induced by smoke, the occurrence of which has sometimes injured or destroyed tender plants.

4. That no basis is supplied upon which to judge the amount of smoke which is necessary to bring about injurious results; the effects described are generally such as have attended exposure to severe conditions.

The loss and damage to property arising from smoke has been tentatively studied in various localities, and estimates based upon fuel consumption have been made. In none of these can the methods be accepted as satisfactory or the results as approximating the truth. Many of the facts involved are variable or indeterminate. It may be noted that:

1. The loss and damage caused by the gaseous products of combustion are due chiefly to their sulphur con-

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[4] Chicago Committee of Investigation.

tent. The investigations of the Chicago Committee show that the extent to which sulphur appears in such gases depends upon the composition of the fuel and not to any great extent upon the manner in which it is burned. Loss and damage, therefore, arising from the gaseous products of combustion are a function of the kind and quantity of fuel burned.

2. The extent of loss and damage arising from the solids in smoke will, other things being equal, depend upon the character of the solids. For example, solids in the form of soot and oily distillates of fuel soil and deface more quickly than solids in the form of coke or ash particles. The former are characteristic of smoke from low-temperature fires, such as those of domestic service; the latter are characteristic of smoke from high-temperature fires, such as those of high-pressure steam boilers and steam locomotives.

An attempt to define the extent of losses regardless of the manner in which they arise at once discloses the lack of a definite or reliable standard of measure. It can not be assumed, for instance, that a large city ought to be as clean as a country village, nor can any ratio of cleanliness be established. It is obvious that the diversified activities of the larger communities are productive of a greater degree of street dust and other forms of atmospheric pollution, as well as of smoke, than those of small towns. The large cities are, in most cases, more congested than the small ones, and this congestion is in itself productive of a greater degree of atmospheric pollution, whether of a preventable or unpreventable nature. In view of the many complex and variable factors involved, any attempt to secure a satisfactory estimate of the financial loss occasioned by city smoke must be more elaborately organized and conducted than any which has thus far been undertaken.

III. THE CITY OF CHICAGO.

Since the discussions which follow concern results which are applicable to the city of Chicago, some brief description of that city must be given.

The fact is clearly recognized that the activities of the city and of its suburbs so intermingle that the interests of residents of city and suburbs are in many respects common. Moreover,

Fig. 1.

The committee's Area of Investigation, emphasizing location of parks and boulevards.

smoke in the atmosphere is easily transferred from city to suburb and from suburb to city. Such considerations lead to the inclusion of considerable territory which is outside of the city in the com-

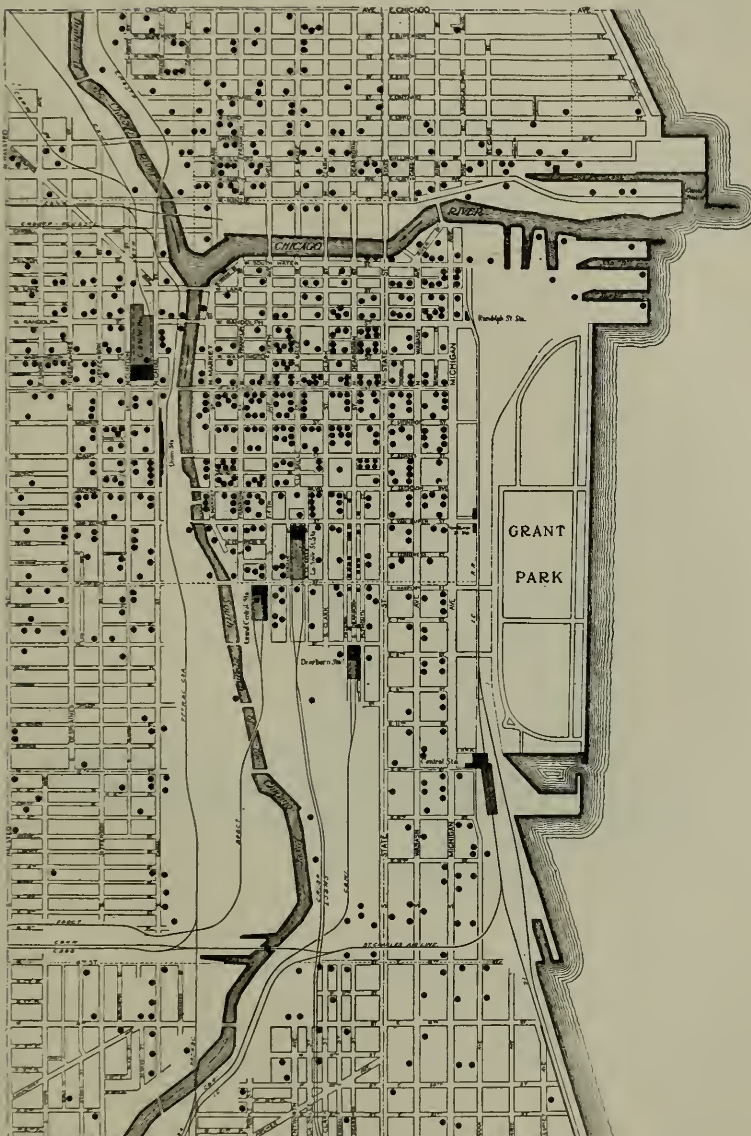
mittee's area of investigation. This area is represented on the official maps of the committee (Figs. 1 and 2) as that which lies between Lake Michigan and the heavy black boundary line.

FIG. 2.

The committee's Area of Investigation, emphasizing location of railroads.

For convenience this area has been divided into two parts. Zone A comprehending the area of the city, and Zone B the area of outlying territory. Zone A includes 194.4 square miles:

FIG. 3.



Section of map showing high-pressure steam boiler plants in Chicago.

Zone B, 233.9 square miles, and the whole Area of Investigation (Zones A and B), 428.3 square miles.

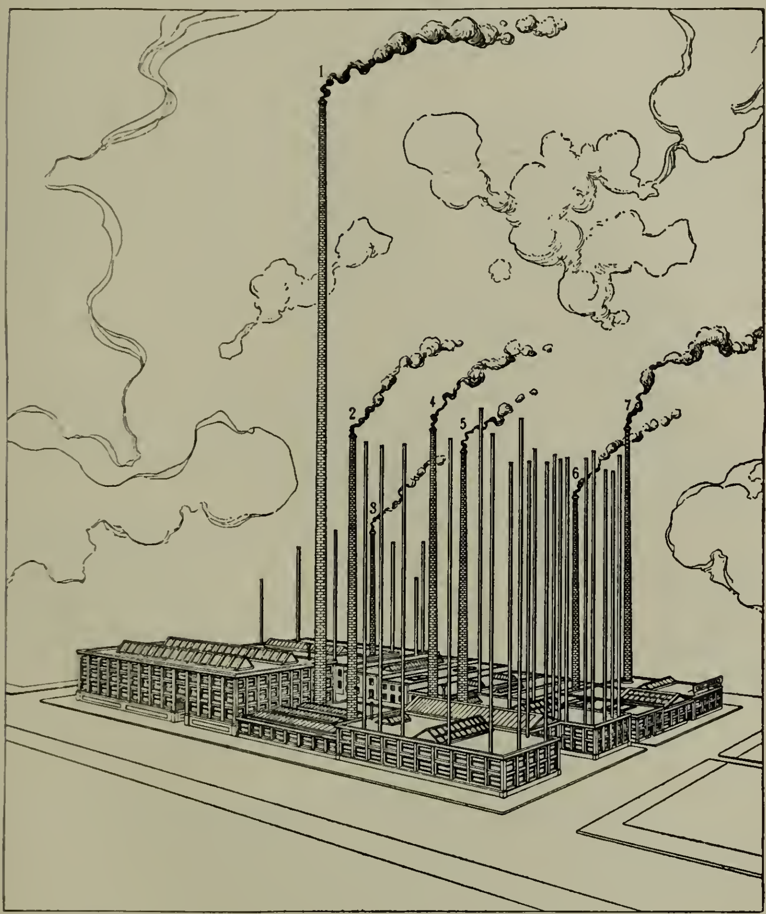
Within this territory 39 different railway companies operate. Of this number, 25 maintain passenger and freight service and 23 are classed as trunk lines, while 14 perform transfer or switching service only. Of the trunk lines, 8 have no main tracks within the city limits, but operate trains into the Chicago terminals over the tracks of other companies. Twelve railroads operate wholly within the Area of Investigation.

The city of Chicago, Zone A, extends north and south a distance of 26 miles, and its average width is approximately 8 miles. It touches on the north the corporate limits of the city of Evanston, and on the south the open prairies beyond Lake Calumet. Its eastern boundary is Lake Michigan and the Illinois-Indiana state line. It presents 23.4 miles of shore line on Lake Michigan. Its "loop district," in which are centralized the city's financial and commercial activities, contains lofty office structures, the principal hotels, and the buildings of the city, county, and national governments. The location of steam-boiler plants in this portion of the city is indicated by Fig. 3 and the chimney flues and smoke-stacks of single block by Fig. 4. The city's manufacturing districts include the extensive establishments in South Chicago, Pullman, the Union Stock Yards, and the central manufacturing district. Its industries engaged in the handling and storing of fuel, lumber, and of other building materials, occupy large areas on both branches of the Chicago River. Its network of steam railroad yards, its shops and other terminal facilities for the care and handling of railroad equipment are well distributed over its area (Fig. 2). Within the city are many beautiful parks and boulevards (Fig. 1), and extensive residential districts.

Zone B, comprising the irregular belt of territory extending around the city of Chicago from the lake on the north to the lake on the south, is represented on the maps as the area between the boundary of the city and the heavy black line bounding the Area of Investigation. It presents 12.9 miles of shore line along Lake Michigan. It includes most of the city of Evanston, nearly two-score suburban villages in Illinois, and the manufacturing cities of Hammond, Whiting, and East Chicago in Indiana; it contains also

extensive areas of unimproved land. It is traversed by all railroads entering the city, and is occupied by many large railroad yards, such as those at Godfrey, Proviso, Clearing, and Dolton in

FIG. 4.



A typical block in the business district of Chicago in which the actual buildings are assumed to give way to buildings of factory height and in which the existing smokestacks and chimneys are assumed to remain at their present heights. The drawing is an isometric projection. The numbers indicate power plant stacks.

Illinois, and those at Gibson and Kirk in Indiana. From the standpoint of railroad activity, Zone B is the hinterland of the city. Trunk and belt lines make it common ground upon which to inter-

change cars entering or leaving Chicago, as well as those destined to points beyond.

IV. FUEL CONSUMPTION IN CHICAGO.

The purpose of the Chicago committee to determine the necessity for changing the motive power of steam locomotives to electric or other power as a means in smoke abatement led naturally to a study of the relative amounts of smoke discharged from different fuel-consuming services, for obviously, if it were shown that a small percentage of the total smoke comes from steam locomotives, the necessity for a change could not be urgent. In the development of this phase of the work six services were recognized, some of which were so subdivided as to give a total of fifteen different groups. The six services were as follows:

1. Steam locomotives.
2. Steam vessels.
3. High-pressure steam stationary power and heating plants.
4. Low-pressure steam and other stationary heating plants (including all domestic heating).
5. Gas and coke plants .
6. Furnaces for metallurgical, manufacturing, and other processes.

All coal consumed was accounted for under this classification; that is, the sum of coal burned in the several services is the total consumption within the Area of Investigation.

The further procedure involved:

1. A determination of coal consumed for each service.
2. A determination for each service of a series of "smoke factors" which would represent the amount of visible smoke, the solid constituents of smoke, and the gaseous products of combustion emitted, per unit weight of coal burned.
3. The combination of the amounts of coal burned in each service with the approriate smoke factors in such manner as to give a relative measure of the smoke discharged by each service.

The fuel consumption for the year 1912 was determined

through the coöperation of many different agencies. All common carriers (railroads and boat lines) made monthly reports throughout the year of their deliveries of revenue coal within the committee's Area of Investigation. While the methods of reporting varied, most carriers made returns from each point of delivery, with the result that many thousands of individual reports were handled by the committee. Coal brought in as company freight was determined as the result of a carefully-conducted investigation. Variations in the amount of coal in store and the extent to which these amounts were affected by reshipments were taken into account. A summary of results thus obtained, applicable to the committee's Area of Investigation, is set forth as follows:

	Tons	Total
Coal and coke delivered by rail as revenue freight	17,563,711	
Coal and coke delivered by boat as revenue freight	1,706,556	
		19,270,267
Coal and coke consumed by steam locomotives in service..	2,555,233	
Coal and coke consumed by steam locomotives at locomotive terminals	260,167	
		2,815,400
Coal and coke consumed by railroad stationary plants....		524,596
Coal and coke consumed by steam vessels within the Area of Investigation		92,368
Decrease in amount of fuel in storage		231,041
		22,933,672
Deductions:		
Coal and coke delivered to steam vessels but not consumed within the Area of Investigation	126,556	
Coal and coke reshipped from points within the area to points within and points outside the area	800,413	
Coal equivalent of the fuel and by-products produced by gas and coke plants	797,817	
		1,724,786
Net total		21,208,886

The origin of the coal consumed within the Area of Investigation is as follows:

Kind of Fuel	Origin	Tons	Per cent. of total
Anthracite	Pennsylvania	1,827,158	8.62
Pocahontas *	West Virginia	1,230,787	5.80
Coke	Various states	3,435,753	16.20
Bituminous	Illinois	9,184,126	46.31
Bituminous	Indiana	3,084,688	14.54
Bituminous	Other states	2,446,374	11.53
Totals		21,208,886	100.00

The consumption of solid fuels for the year 1912 within the Area of Investigation by services was as follows:

	Tons
Steam locomotives	2,815,400
Steam vessels	92,368
High-pressure stationary power and heating plants	9,147,334
Low-pressure steam and other stationary heating plants	4,646,910
Gas and coke plants	253,867
Furnaces for metallurgical, manufacturing and other processes	4,253,007
Total	21,208,886

The consumption of solid fuels within the limits of the city of Chicago (Zone A) for the year 1912 was as follows:

	Tons
Anthracite	1,633,002
Pocahontas	1,174,742
Coke	3,099,302
Bituminous (all services)	11,675,477
Total	17,582,523

The consumption of solid fuels within the city (Zone A) for the year 1912, by services, was as follows:

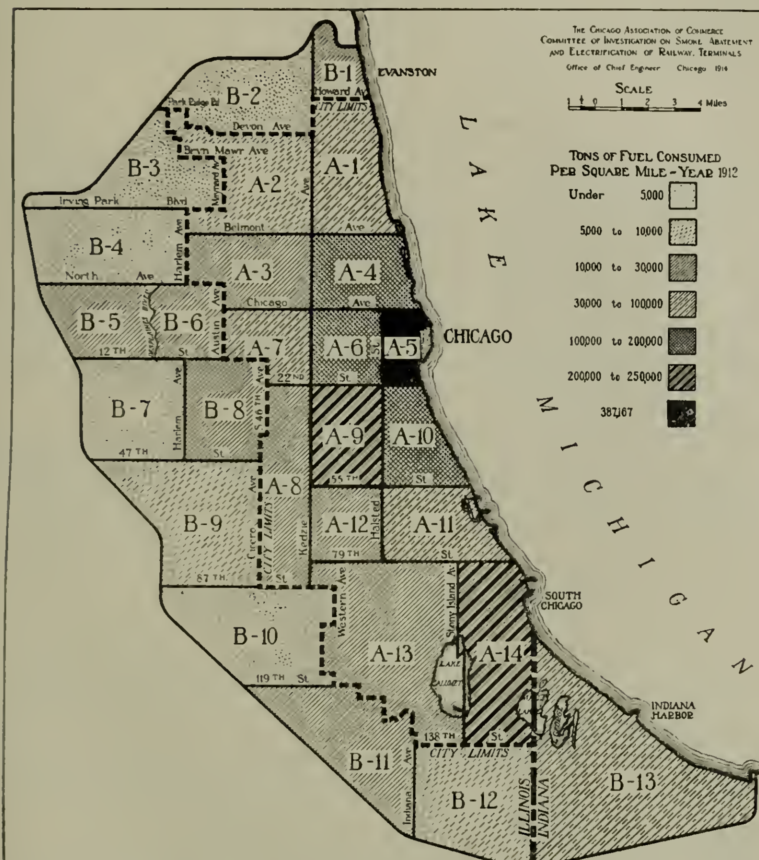
	Tons
Steam locomotives	2,099,044
Steam vessels	81,375
High-pressure stationary power and heating plants	7,316,257
Low-pressure steam and other stationary heating plants	4,154,746
Gas and coke plants	234,551
Furnaces for metallurgical, manufacturing, and other processes	13,696,550
Total	17,582,523

*It has not been possible to determine the degree of accuracy attending the use of the term "Pocahontas" in the reports received through different agencies. It is probable that as here used it applied to any semi-bituminous coa from the West Virginia region.

The density of fuel consumption for different district areas is set forth by Fig. 5.

In addition to the solid fuels consumed, it is estimated that there were used within the committee's Area of Investigation dur-

FIG. 5.



Relative density of fuel consumption in the several zone districts.

ing its statistical year appproximately 3,511,000 barrels of fuel oil, chiefly in industrial fires. This amount of oil is equivalent to 1,170,000 tons of coal, or to about 5½ per cent. of the city's annual consumption of solid fuel. The amount of kerosene consumed.

chiefly in lighting, amounted to 231,579 barrels, and the amount of gasoline and naphtha used, chiefly for automobile engines, amounted to something more than a half million barrels.

These figures serve to disclose the enormous quantities of fuels consumed within the Area of Investigation. It is obvious that the coal-consuming industry touches the activities of the municipality at many different points. The life of the city is, in fact, dependent upon its preservation.

V. THE PROPERTIES OF SMOKE.

Investigations concerning the so-called smoke nuisance have hitherto dealt chiefly with smoke as a visible pollution. The Chicago committee early became convinced that a more general definition should be adopted, and for its own purpose it defined smoke as the "gaseous and solid products of combustion, visible and invisible, including, in the case of certain industrial fires, mineral and other substances carried into the atmosphere with the products of combustion."

According to this definition, smoke may be regarded as possessing a threefold character, to each aspect of which suitable standards of measure may be applied. These are as follows:

1. Visible properties.
2. Solid constituents.
3. Gaseous constituents.

The committee's procedure, by which it was sought to evaluate the smoke of different services under the three heads given, can not here be given, though the fact should be noted that many of its methods were original and that its office and field staff to which this aspect of the problem was assigned numbered at one time nearly 100 men. In the discussion of results which follows numerical facts will only be given for the city of Chicago (Zone A).

VI. VISIBLE SMOKE IN CHICAGO.

The relative standing of different services with reference to visible smoke within the limits of the city of Chicago has been set forth by the committee, as follows:

RELATIVE AMOUNT OF VISIBLE SMOKE PRODUCED BY EACH SERVICE, AS DETERMINED BY THE RINGELMANN METHOD.

Zone A (The City of Chicago).

Service	Fuel consumed, tons	Average smoke density, per cent.	Relative standing, per cent.
Steam locomotives:			
Yard	1,049,516	16.73	10.25
Road freight	136,115	25.32	2.01
Freight transfer	354,802	22.16	4.59
Passenger transfer	21,370	15.11	0.19
Through passenger	176,761	20.09	2.07
Suburban passenger	155,327	17.03	1.54
Locomotive terminals	205,153	11.77	1.41
Totals	2,099,044	.....	22.06
Steam vessels:			
Tugs and lighters	35,153	14.04	0.29
River barges, dredges, pile-drivers, etc	10,525	22.99	0.14
Lake steamers and barges	35,697	14.79	0.31
Totals	81,375	.....	0.74
High-pressure steam stationary power and heating plants, including: Public service corporation plants; Municipal plants; Steam railroad plants; Office buildings, hotels and schools; Manufacturing plants	7,316,257	10.42	44.49
Low-pressure steam and other stationary heating plants, including: Large and small buildings; Large and small apartments; Residences	4,154,746	1.62	3.93
Gas and coke plants:			
Public service (not including boiler power plants)	139,525	0.00	0.00
Other service (not including boiler power plants)	95,026	2.69	0.15
Totals	234,551	.....	0.15
Furnaces for metallurgical, manufacturing, and other processes, including: Steel plants, foundries, forges, and allied processes (not including boiler power plants); Brick, pottery, and allied processes; Miscellaneous manufacturing, rendering, and other processes	3,696,550	13.27	28.63
Grand totals	17,582,523	.....	100.00

The results are of interest from many points of view. They show that nearly half of the total visible smoke is made by high-pressure steam stationary plants; that such plants and industrial fires combined make three-quarters of the total smoke, and that the railroads make approximately one-fifth of the total smoke. In view of the relative extent of the railroad establishments in Chicago, it would appear that the percentage of railroad smoke in the atmosphere of that city would be at least as great as that in the atmosphere of other large American cities.

Visible smoke arising from the burning of bituminous fuels is the result of a failure, either in the design of the furnace or in its operation, to observe certain conditions which are the necessary accompaniments of so-called "smokeless" combustion. These conditions may be summarized briefly as follows:

1. The coal must be introduced into the furnace at such a point and distributed in such a way that the gases distilled from it will be required to pass over or through the incandescent portions of the fire. The observance of this condition will, in most cases, expose the distillates to a temperature sufficiently high to insure their ignition. These distillates, if not burned, are prolific sources of visible smoke.

2. The stream of gases from the fuel must be heated quickly and kept at a high temperature until the process of combustion is well advanced. The presence of a fire-brick arch under which the distillates may be burned, and the passing of the distillates through the bed of fire, are aids in securing this condition.

3. The avoidance of heat-absorbing surfaces in close proximity to the burning distillates, the interposition of which tends to cool the gases, to suppress combustion, and to produce visible smoke.

4. The admission of air, by which combustion is stimulated, should be provided for at proper points and should be carefully regulated.

5. The proportions of the furnace should be such as will provide an ample flameway or combustion chamber. The observance of this condition is necessary in order that the time occupied by the gases in passing through the furnace may be sufficient to permit them to burn completely.

If all of these conditions are observed, the smoke arising from fires of bituminous coal will be nearly, if not wholly, invisible, but there are many practical difficulties to be met by one who seeks to observe them; as a consequence, the products of combustion issuing from bituminous coal fires are commonly more or less visible.

The importance of the flameway in relation to visible smoke is at once apparent. Fuels burn with different lengths of flame, depending upon their composition. For example, coke and anthracite coal, the principal combustible element of which is carbon, burn with a very short flame. The whole process of combustion takes place at or near the surface of the fuel. Such fuels can be burned without developing visible smoke, even though the flameway may be short and otherwise restricted.

The bituminous coals of Pennsylvania and Ohio are relatively lower in carbon and higher in volatile matter than coke or anthracite coal, and the volume of gases distilled from them is greater. The process of intermixing and combining the combustible gases thus distilled with the air necessary to their combustion takes an appreciable period of time; hence the flame is comparatively long and the furnace must be such as to supply room in which combustion may proceed.

The bituminous coals of Illinois are higher in volatile matter than are the bituminous coals of Pennsylvania and Ohio, hence they require a still longer flameway.

The temperature of the flameway is also important in its relation to visible smoke. It is because of low temperatures that the bituminous coal fires of stoves and small furnaces, receiving attention at infrequent intervals, are sometimes prolific sources of visible smoke. A large mass of Illinois coal placed upon the surface of a fire at once lowers the furnace temperature to such a degree that the distillates which come from the fresh coal pass off without igniting. Progress in the art is steadily finding new means, by the application of which a satisfactory temperature even of a small fire may be maintained. In the development of such means the brick arch has had an important part.

Furnace draft is important in its relation to visible smoke. Draft is the governor controlling the rate of combustion. If the draft is weak, the rate of combustion will be low and the temperature of the fire may be lower than that which is necessary for the

suppression of visible smoke. A strong draft also stimulates the activity of the intermixing currents in the furnace and so aids combustion. Strong drafts normally imply high rates of combustion and high furnace temperatures, so that, in general, it may be said that the abatement of visible smoke is promoted by increasing the draft of the furnace. Here again the solution of the problem is comparatively easy in its application to large fires and extremely difficult in its application to small fires.

Air supply is important in its relation to visible smoke. Perfect combustion implies that all of the carbon in the fuel shall have an opportunity to combine with oxygen. The oxygen needed for this purpose is supplied by the air which is borne into the furnace by the action of the draft. If the supply of air is deficient, the burning process will be incomplete and visible smoke will result. To avoid such an occurrence, it is customary to provide for a larger supply of air than is needed to support combustion, and, under some conditions, the excess supply is very large. While it sometimes happens that an excessive supply of air tends to lower the temperature of the fire, to cool the flameway, and, under certain conditions, to increase the visible smoke, the fact remains that up to a certain limit, which may vary with the construction of the furnace, increasing the air supply aids in reducing the visible smoke.

No one thing has been more potent in contributing to the elimination of visible smoke than the advent of mechanical stokers and other forms of automatic furnaces. These devices represent results achieved in the development of furnace design to meet the requirements of theoretical conditions. Their introduction implies not only automatic feeding, but the acceptance of other conditions essential in the elimination of visible smoke. Mechanical stokers provide for the progressive movement of the fuel into the furnace; they generally provide for an ample flameway and a brick arch under which the initial combustion may proceed. They are rarely installed except where satisfactory draft conditions are assured; as a consequence, it is commonly assumed that the mechanical stoker or hopper-fed furnace is a smoke-abating device, and in general this assumption is justified. This statement does not imply that mechanical stokers or other devices for automatic stoking will in themselves suffice to make smoke invisible. It is only when they are properly operated that they can be depended upon to give satisfactory results.

The investigations of the Chicago committee are impressive in the testimony they yield as to the value of care in firing as a means of reducing visible smoke. This statement applies, whatever may be the form of furnace used or apparatus employed. Careless hand-firing results in large volumes of visible smoke; careful, frequent, and progressive hand-firing results in the elimination of most of this smoke. The careless manipulation of the automatic stoker may result in the production of visible smoke; its careful handling will suffice to eliminate most of this smoke. A comparison of the smoke arising from any coal-consuming service, as maintained within the city limits of Chicago where its operation is subject to municipal inspection, with that arising from the same class of service outside the city where no restrictions are imposed, will disclose a lower density of smoke within the city than outside. That is, where it is necessary to reduce the visible smoke, the attention needed to secure such a result is given; where it is not necessary, the effect of neglect is to be seen in the result.

Smoke abatement is often an indirect means of effecting economy. While the constituents of smoke which impart visibility to it represent a relatively small amount of heat, and while, as a consequence, no great saving can be directly effected through the suppression of visible smoke, it is nevertheless true that the process of smoke suppression may open channels through which important benefits may accrue. For example, the suppression of smoke implies the substitution of good for poor fire-room practice. If the fire-room is large, smoke abatement implies the use, the proper maintenance, and the skilful manipulation of automatic firing devices. If the fire-room is small, it implies the exercise of superior skill and intelligence on the part of the fireman. In general, smoke suppression involves a reorganization of fire-room administration and methods, and a reorganization stimulated for the purpose of reducing smoke opens the way to other reforms, the net effect of which may constitute a material saving in the operation of the plant.

VII. THE SOLID CONSTITUENTS OF CHICAGO SMOKE.

The contributions of the different fuel-consuming services to the solid elements of atmospheric pollution for the city of Chicago have been set forth by the committee as follows:

Amount of Solids Emitted in Smoke from Each Service and Relative Standing of Services.

Zone A.

Service	Fuel consumed		Solids in smoke		
	Kind	Tons	In per cent. of fuel consumed	Tons	Per cent. of total
1	2	3	4	5	6
Steam locomotives:					
Yard	Pocahontas	23,049	1.778	410	0.14
	Bituminous	1,026,467	0.471	4,835	1.59
Road freight	Bituminous	136,115	2.642	3,596	1.18
Freight transfer	Pocahontas	2,996	1.470	44	0.01
	Bituminous	351,806	0.362	1,274	0.42
Passenger transfer	Pocahontas	885	1.778	16	0.01
	Bituminous	20,485	0.471	96	0.03
Through passenger	Pocahontas	2,441	3.116	76	0.02
	Bituminous	174,320	3.116	5,432	1.78
Suburban passenger	Bituminous	155,327	3.866	6,005	1.97
Locomotive terminals	Bituminous	205,153	0.471	966	0.32
Totals		2,099,044	1.084	22,750	7.47
Steam vessels:					
Tugs and lighters	Anthracite	112	0.223	*	†
	Pocahontas	3,748	1.290	48	0.02
	Bituminous	31,293	1.222	382	0.12
River barges, dredges, etc.	Pocahontas	1,186	1.290	15	0.01
	Bituminous	9,339	1.222	114	0.04
Lake steamers and barges	Bituminous	35,697	1.222	436	0.14
Totals		81,375	1.223	995	0.33
High pressure steam stationary power and heating plants:					
Public service, municipal, steam railroad, office buildings, schools, hotels & manufacturing	Anthracite	5,291	0.223	12	†
	Coke	2,121	0.223	5	†
	Pocahontas	262,196	0.649	1,702	0.56
	Bituminous	7,046,649	0.811	57,148	18.78
Totals		7,316,257	0.805	58,867	19.34
Low-pressure steam and other stationary heating Plants:					
Buildings, apartments and residences	Anthracite	1,577,761	0.138	2,177	0.71
	Coke	41,181	0.223	92	0.03
	Pocahontas	849,185	0.490	4,161	1.37
	Bituminous	1,686,619	1.171	19,750	6.49
Totals		4,154,746	0.630	26,180	8.60

AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES.

Zone A.—Continued.

Service	Fuel consumed		Solids in smoke		
	Kind	Tons	In per cent. of fuel consumed	Tons	Per cent. of total
1	2	3	4	5	6
Gas and coke plants (exclusive of boiler power plants):					
Public service	Anthracite	5,882	No tests made		
	Coke	133,643			
Other service	Anthracite	245			
	Pocahontas	2,366			
	Bituminous	92,415			
Total		234,551			
Furnaces for metallurgical, manufacturing, and other processes (exclusive of boiler power plants):					
Steel plants, foundries, forges, and allied processes	Anthracite	31,442	1.798	565	0.19
	Coke	2,909,360	6.380	185,617	60.98
	Pocahontas	26,368	1.290	340	0.11
	Bituminous	651,187	1.084	7,059	2.32
Totals		3,618,357	5.350	193,581	63.00
Brick, pottery and allied processes	Coke	206	1.798	4	†
	Pocahontas	0	0	0	†
	Bituminous	8,165	15.560	1,270	0.42
Totals		8,371	15.219	1,274	0.42
Miscellaneous manufacturing, rendering and other processes	Anthracite	12,269	0.223	28	0.01
	Coke	12,791	1.798	230	0.07
	Pocahontas	322	1.290	4	†
	Bituminous	44,440	1.084	482	0.16
Totals		69,822	1.066	744	0.24
Sub-totals		3,696,550	5.291	195,599	64.26
Grand totals		17,582,523	1.731	304,391	100.00

* Less than 0.5 ton.
† Less than 0.005 per cent.

It will be seen that the greatest contributors to this form of atmospheric pollution are the industrial fires; that stationary boiler plants are relatively large contributors, and that steam locomotives contribute a relative small percentage of the total.

The polluting effects of the solid constituents of smoke are dependent to some extent upon their chemical composition. The presence of hydrocarbons is generally more objectionable than the presence of mineral matter or unconsumed carbon. Hydrocarbons constitute a large proportion of the distillates of coal. They appear in the atmosphere in the form of soot, which readily soils and blackens. Soot is easily transported by air currents. Any service, therefore, the smoke of which is high in hydrocarbons constitutes a more objectionable source of atmospheric pollution than a service the smoke of which is low in such distillates.

Not all of the solids in smoke are of fuel origin, though, for purposes thus far set forth, it is assumed that solids passing out of chimneys with the products of combustion may be regarded as solid constituents of smoke. Since the investigation was for the purpose of determining the relative contributions of different fuel-consuming services to the total quantity of dust in the atmosphere, this assumption is not misleading, and it has the advantage of supplying a definite basis upon which conclusions may be established. Its effect, however, has been to emphasize the importance of certain metallurgical and other industrial fires which send out with the products of combustion a heavy lading of metallic or mineral dust. Fires which are sustained by coke and by fuel gas, as well as those which are sustained by coal, may, upon this basis, be prolific producers of dust.

The amount and character of the solid constituents of smoke, so far as they are of fuel origin, are functions of furnace conditions. The path of the solids is that which is followed by the currents of air and gases; these currents enter the furnace through the bed of fire, and, passing along the flameway, enter by whatsoever channel may be provided into the smokestack, from which they pass on to the atmosphere. A weak draft, such as that which normally prevails in connection with domestic fires, implies fine dust particles and soot flakes only in the smoke, whereas a strong draft, such as that which commonly prevails in boiler plants served by lofty chimneys and in steam locomotives, implies the discharge of solid particles of considerable size.

Changes in the rate of combustion produce changes in the temperature of the fire and in the character of the solids in smoke. Low draft values imply low rates of combustion, low furnace temperatures, and solids in smoke consisting largely of particles

condensed from distillates driven out of the freshly-applied fuels while in the process of being heated to the point of ignition. The solids include also very fine particles originating in the fuel and its ash which are sufficiently light to be borne away upon the current of the feeble draft. It is an interesting fact, as disclosed by the results of the committee's investigations, that, while the individual particles discharged from fires of low temperature may be small, the percentage of the coal burned which is represented by the hydrocarbons and soot passing off with the smoke is relatively high. It is because of this high percentage of hydrocarbons that the solid constituents of smoke emitted from fires of low temperature constitute an important factor in the total pollution of the atmosphere of a city.

High rates of combustion imply high furnace temperatures and smoke low in hydrocarbons and relatively free from soot. Solids from such fires include particles of partially-consumed fuel which, in the processes of the furnace, are exposed to the action of a draft too strong to permit them to retain their place on the fire-bed. They include portions of fine ash which are readily caught up and carried away, also spherical slag particles picked up from the fire-bed in a liquid state and solidified as they pass on their course into the atmosphere. The solid constituents of Illinois coal, when this coal is consumed in fires of high temperatures, yield a considerable percentage of these spherical slag particles, varying in size from those which are microscopic to others approaching one-eighth of an inch in diameter. All such particles have a honeycomb structure and, when crushed under foot or by traffic in the streets, yield a fine powder which is easily borne away upon the wind.

An important fact clearly defined by the investigations of the committee, the significance of which has not before been generally appreciated, concerns the omnipresence of solids in smoke discharges. As shown in the preceding sections, the quantity and character of the solids in smoke may vary greatly, but smoke arising from solid fuels is never free from such solids. Again, the amount of solids discharged has no direct relation to visibility. A stack may appear smokeless to the eye and yet be the source of a heavy discharge of fuel dust. The adoption of anthracite coal or of coke as a fuel will serve to make stack discharges invisible, but will not eliminate the dust discharge.

VIII. GASEOUS CONSTITUENTS OF SMOKE IN CHICAGO.

The limited significance which can be assigned to the facts makes it unnecessary to present in this connection a detailed statement of the gaseous products of combustion discharged by different fuel-consuming services.

Notwithstanding the large volume of gaseous products of combustion which are emitted into the atmosphere of a city, little trace of them is disclosed by a chemical analysis of the atmosphere. The explanation is, of course, to be found in the fact that, while the volume of the polluting discharge is great, that of the atmosphere is vast, and its power to absorb and diffuse the streams of pollution which enter it, great. The following illustration will prove serviceable in increasing one's understanding of this aspect of the matter.

The total volume of air-diluted gases discharged each day from the stacks of Chicago amounts approximately to 47,000,000,000 cubic feet. The average wind velocity recorded in the city during the year 1912 was 13 miles an hour. The area of the city is 194 square miles. Assuming that the diluted gaseous products of combustion rise uniformly over this area as from an orifice and are borne away in a horizontal film by the wind, the thickness of the film at any given time would be approximately one-third of an inch. But the smoke discharges making up this film are air diluted; if the air is extracted the thickness of the film would be reduced by 75 per cent.; that is, the film of the gaseous products of combustion becomes approximately eight one-hundredths of an inch in thickness. It will, of course, be understood that no such film actually exists, since the diffusion of the products of combustion into the atmosphere begins as soon as they are discharged; but the capacity of the atmosphere to absorb these gases can be better comprehended when one considers that its duty is that of continuously absorbing through diffusion a horizontal film of the gaseous products of combustion less than one-tenth of an inch in thickness.

IX. ALLIES OF SMOKE IN ATMOSPHERIC POLLUTION.

Thus far in the discussion of atmospheric pollution attention has been given only to smoke, but not all that pollutes the atmosphere is of fuel origin. Dust from many sources mingles with that of smoke to make up the sum-total of the dust content of Chicago's atmosphere.

If all the fires of a city were stopped, dust and dirt would remain in its atmosphere. When the atmosphere is dry and the wind velocity high, the air is filled with dust particles. This manifestation is not confined to the streets, for dust finds its way into buildings from which it must be removed by cleaning processes.

Atmospheric pollution can not be reduced to a minimum through attention to smoke abatement alone. In order to accomplish its reduction, attention must be given to all of those processes and activities of the city which give rise to dust or which deal with the collection and disposal of city dirt and waste.

The amount of city dust is a function of efficiency in city sanitation. It depends upon standards of cleanliness observed in the maintenance of streets and alleys and upon methods employed in cleaning them. It is important, therefore, in considering means to be employed in reducing the atmospheric pollution of the city, to give due attention, not only to smoke, but to all other sources from which city dust arises.

Some of the primary sources of atmospheric dust are bare-ground areas, including unimproved streets and alleys, fuel and building materials stored and in transit, building operations, street construction and repairs, the abrasion of streets and sidewalks under traffic, and back-yard and roof accumulations and activities. Secondary sources appear in conditions which permit dust, once settled from the atmosphere, to be redistributed by the wind.

X. ATMOSPHERIC POLLUTION AS DISCLOSED BY A STUDY OF THE ATMOSPHERE.

Paralleling its studies of fuel consumption and of smoke discharges, the Chicago committee undertook:

1. A study of the meteorological conditions in Chicago and in other cities, that the relation between meteorological conditions and atmospheric pollution might be shown.

2. A study of the atmosphere of cities as disclosed by a review of scientific literature bearing upon the subject.

3. An extensive examination of the atmosphere of Chicago involving filtration tests and chemical analyses of air samples drawn from many different parts of the Area of Investigation.

The filtration tests and analyses of air were made by means of a portable laboratory mounted upon a suitable motor truck, the equipment of which was so arranged that the laboratory might take up any predetermined location from which it could draw samples of atmospheric air continuously for a period of several hours' duration. This laboratory was kept in operation for a full year.

The results obtained from the study of the atmosphere justify certain general conclusions, some of which are as follows:

1. Wind movement has the effect of dissipating the polluting constituents of the atmosphere and of rendering them less objectionable. The extent to which products of combustion are effective in polluting the atmosphere may be said to vary inversely as the velocity of the wind.

2. Temperature as a factor in atmospheric pollution is of indirect importance only; it exerts an influence upon other atmospheric conditions, such as wind and humidity, which are factors of great importance. This relationship between temperature and other conditions is, however, complex.

3. High relative humidity serves directly to intensify the effects of atmospheric pollution, in that it promotes the formation of fogs or mists which hold the products of combustion in the atmospheric strata near the earth.

4. Precipitation is an effective purifier of the atmosphere. It operates to wash out a large portion of the polluting substance suspended in the air.

5. Sunshine, as affected by atmospheric pollution, serves as an indirect measure of the extent of the pollution.

6. In general, the combination of meteorological conditions which tends to intensify the effects of polluting substances in the air includes low wind velocity, comparatively low temperature, high relative humidity, and absence of sunshine.

7. Chicago's weather conditions, in their relation to the maintenance of a pure and wholesome state of the atmosphere, are far superior to those of most other cities of the United States and Europe.

8. In general, those polluting constituents of the atmosphere which are regarded as being most objectionable consist largely of solid particles which serve to soil or injure buildings and materials of every sort. These constituents have their origin largely in the combustion of fuel, and appear in the form of distillates of coal, unconsumed carbonaceous material, or ash. Ash in the atmosphere is practically devoid of color, and its presence is not readily identified. It is not as detrimental or apparent in its effect upon material objects as are the sooty or carbonaceous materials.

9. The quantity of solid materials in the atmosphere of Chicago varies from 0.321 to 1.958 milligrammes per cubic metre. Values of record for other cities are not numerous.

10. The solid materials or particles present in the atmosphere of Chicago include not only solid products of combustion, but also mineral, vegetable, and animal *débris*. The evidence based upon atmospheric analyses is to the effect that all sources of dust contribute to the pollution of the atmosphere.

11. The content of carbon dioxide in the atmosphere of cities, as disclosed by the reports of many investigations, does not appear to vary materially. The values determined for this substance, from samples taken of Chicago's atmosphere, correspond very closely to those reported for other cities.

13. Carbon monoxide, while in itself a poisonous gas, does not ordinarily constitute an important element in atmospheric pollution. No determinations of this gas were made in connection with the air analyses in Chicago. Values resulting from tests conducted in Paris and in Berlin indicate its presence only in minute quantities.

13. The ammonia content of the atmosphere of Chicago is small. The values reported for other cities are many times greater than those for Chicago.

14. Chlorine is not present in the atmosphere of Chicago in sufficient quantities to have any significance except as an indication of local conditions.

15. The gaseous compounds of sulphur are products

of combustion, and in the atmosphere of Chicago they vary from a minimum of 0.217 to a maximum of 1.104 milligrammes per cubic metre. The values reported for other cities, so far as obtainable, are generally higher.

16. Sulphur compounds, which eventually are converted into sulphuric acid, are, from the standpoint of atmospheric pollution, the most objectionable gaseous products of combustion. Sulphuric acid tends to exert an important influence in the disintegration of building materials of all kinds, and produces deleterious effects upon furnishings, clothing, and merchandise.

17. With reference to the geographical distribution of polluting substances in Chicago's atmosphere, it may be stated conclusively that the pollution is greatest in those localities where the greatest industrial activities prevail. The atmosphere in the loop district and in the neighborhood of railroad terminals is more seriously polluted than that of outlying districts.

18. The polluting constituents of the atmosphere have their origin in many kinds of industrial activity. Of the solid elements of pollution in the atmosphere of Chicago, not more than two-thirds of the total is of fuel origin.

XI. ELECTRIFICATION AS A MEANS IN SMOKE ABATEMENT.

It has been proposed to require the electrification of the steam railway terminals of Chicago as a means of smoke abatement. The results, to which reference has already been made, supply a basis from which to estimate the effects which would be produced by such a change. The proposal brings into prominence three important factors which enter into such a problem. They are as follows:

1. The smoke discharges from the steam locomotive constitute a definite source of atmospheric pollution. The fundamental factor is that of determining the percentage of the total smoke of Chicago which is contributed by the steam locomotive.

2. The electric operation of Chicago's railroad terminals must depend upon the existence and operation of steam-driven electric generating stations. Such sta-

tions must burn coal, and this will give rise to smoke. The complete elimination of the steam locomotive, therefore, while serving to free the atmosphere of Chicago from all locomotive smoke, must lead to the introduction of new sources of smoke in the form of power stations. The benefits in smoke abatement lie in the difference between the amount of smoke made by steam locomotives and that which will be made by the electric power stations.

3. Smoke is not the only polluting constituent of Chicago's atmosphere. Since atmospheric dirt arises from other sources, a given reduction in the amount of smoke will not produce an equal reduction in the amount of atmospheric dirt. If all the smoke of Chicago were eliminated, there would still be dirt in Chicago's atmosphere.

With this understanding of the general problem, it will be of interest to note that the facts which were developed by the Chicago committee permitted a quantitative measure of the several effects considered to be set forth. It is not claimed that these are directly applicable to the conditions of other cities, but they are not without significance in such a relation. The committee's conclusions as to the benefits to be secured through electrification may be summarized as follows:

1. The amount of visible smoke discharged into the atmosphere of Chicago will be reduced by not more than 20 per cent.

2. The amount of solid constituents of smoke (soot, ash, and fuel particles) discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.

3. The amount of dust and dirt arising from all sources in the atmosphere of Chicago will be reduced by not more than 4 per cent.

4. The volume of gaseous products of combustion discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.

It is upon the basis of these facts that the merit of any proposal involving complete electrification as a means in smoke abatement must be considered. In the further consideration of this matter the Chicago committee has discussed at length such

questions as the technical feasibility of electrification, the cost and the financial practicability of such a change, with conclusions which need not be herein set forth.

Obviously the electrification of railway terminals can serve to reduce or to eliminate the smoke from a single fuel-consuming service. The reduction of smoke from other services, especially from boiler plants, manufacturing industries, and domestic fires, is a matter of first importance. Various means, such as the more extensive use of gas fuel, smoke washing, and the precipitation of smoke by electrical means, now have limited use and are being suggested for wider application. The detailed discussion of these aspects of the general problem does not come within the province of this paper.

XII. SIGNIFICANT FACTORS IN THE PROBLEM OF SMOKE ABATEMENT.

The work of the Chicago committee shows clearly certain facts which will not fail to interest other communities.

Among the factors in the problem, the significance of which has not commonly been recognized, are six which are worthy of especial emphasis in this connection. The first concerns the number and diverse character of the sources of smoke. It can not longer be urged that this or that particular interest produces the smoke of Chicago; all interests contribute to it. The business man can no longer attach blame to the apartment-house owner, nor the apartment-house owner to the railroad, nor the railroad to the manufacturer, for all are joint contributors to the sum-total of Chicago's smoke. As joint contributors they are jointly responsible for the resulting atmospheric pollution. The problem of smoke abatement, as disclosed by the investigations of the committee, can not be effectually dealt with by giving attention to a single segregated interest; it is one in which every interest must be given attention. It is the problem of the whole city.

A second significant fact disclosed by the researches of the committee is that which emphasizes the relatively great importance of the solid constituents of smoke. Hitherto most discussions concerning smoke, and practically all measures designed to show the extent of atmospheric pollution resulting from it, have dealt only with its cloud effects. It now appears that the cloud effects produced by smoke are of secondary importance as com-

pared with effects produced by the soot and dust of smoke. The problem of smoke abatement, therefore, as viewed in the light of the committee's disclosure, is not entirely or largely a problem of suppressing visible smoke, but is one of suppressing the shower of dust and cinders constantly falling from a smoke-polluted atmosphere.

The third important fact disclosed by the committee's researches is to the effect that atmospheric pollution is not entirely the result of soot and dust in their initial descent to the exposed surfaces of the city, but that such material is subject to secondary flights which persist until some exceptional cleansing process eventually eliminates them. Moreover, the sum-total of atmospheric dirt includes, with the solids of combustion, considerable amounts of dust arising from many activities incident to the life of the city. The problem, therefore, of reducing to a minimum the sum-total of atmospheric dirt is not entirely a problem in smoke abatement, but, to a considerable extent, a problem concerning municipal cleanliness; it must deal with the solid constituents of smoke and with every source from which these arise; it must also deal with all accumulations of dirt in a manner which will promote the cleanliness of the city.

The fourth significant fact is to be found in the obvious tendency of all sources of atmospheric pollution to increase. The fuel-consuming industries of the city are expanding; the traffic of the city streets is increasing, and the amount of merchandise handled in and out of the city is growing year by year. Improvements in the methods of burning fuel or of city cleaning imply an improvement in atmospheric conditions only in a relative sense. The elimination of an entire fuel-consuming service would reduce the amount of pollution entering the atmosphere at the time of its accomplishment, but would constitute no guarantee that the sum-total of atmospheric pollution might not increase subsequently to even greater amounts. Improvement in service may, therefore, result only in checking an undesirable growth. This fact emphasizes the importance of giving attention to every means which can be relied upon to reduce the production of polluting agencies at their source.

The fifth fact to be emphasized is to the effect that a revolution in practice which will result in the elimination of existing sources of atmospheric pollution is not to be expected: first, be-

cause present-day knowledge is insufficient to supply the necessary means; and, second, because the immediate application to all sources of pollution, even of such means as are now available, is mechanically and financially impracticable. However urgent the need, progress in satisfying it must be gradual; it must be evolutionary. Chicago is not peculiar among the cities of the world in the possession of this problem. Every great centre of population is confronted with it. Its intrusion is part of the price which is paid for the privilege of maintaining the activities and the concentration of population which characterize the modern city.

Wherever fuel is burned certain effects appear. These may take the form of visible smoke or of tar or dust emissions, and they must always appear in the form of gaseous products of combustion. As a consequence, objections to smoke are valid only in so far as they may be based upon conditions which are avoidable, and ill-advised restrictions against the use of fuel are not only unreasonable, but harmful to the larger and better interests of the community. It is for this reason that the problem of smoke abatement can not be solved by any simple campaign for the enforcement of restrictions. It is a question which, in all its aspects, is of the highest importance to the welfare of the city. It is a scientific question. It can not safely be answered until many local conditions have been studied and defined. It is a living question, since it assumes new aspects as the state of the art develops.

Finally, it should be obvious that the detailed development of this problem by any city must concern itself with all of the different manifestations of smoke as presented by every different service. This is the sixth significant fact. The real problem in smoke abatement is, in fact, not one of legislation or of inspection, but one of bringing together an enlarged fabric of facts concerning possibilities in the proper utilization of fuel by which legislation and inspection may be safely guided.

That this need may be met in Chicago, the Committee of Investigation has recommended the appointment of a permanent Pure Air Commission which shall be supported by liberal appropriations, which shall be active in the development of scientific research, and which shall have authority in many matters touching the industrial, commercial, and municipal activities of the city.

THE TURPENTINE INDUSTRY IN THE SOUTHERN STATES.*

BY

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A RAILWAY trip through the coastal plain of the South Atlantic and Gulf States, from North Carolina to Texas, shows on every side fallen and charred remnants of trees, stumps innumerable, and occasional huge piles of sawdust. It is a desolate scene in those sections where agriculture has not yet been developed. It represents the destructive path of the naval-stores industry, followed more or less closely by that of lumbering, through that rich, natural heritage of long-leaf pine forests which originally covered completely this entire portion of the country.

From these forests the world has received its chief supply of spirits of turpentine and rosin, averaging in value in recent years some forty or fifty million dollars annually. Yet in the production of this great crop only a very few have received for their toil more than a bare livelihood. The great mass of the turpentine operators have toiled throughout the years in rugged earnestness, in robust health from the out-of-door life in the pine forests,—but always on the outer edge of developing civilization, with few of the comforts and conveniences of life, indifferent to the utter lack of efficient business methods in their operations, and strongly wedded to woods practices which have been handed down from generation to generation as they steadily moved from North Carolina toward Texas.

If the traveller, however, should leave the main lines of travel in Florida or the more westerly states, and by tram or team reach some of the more remote sections, he would find beautiful virgin forests of this same long-leaf pine, the rich brown trunks of

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the trees, free from low-lying limbs, bearing aloft rich crowns of green, and firmly rooted below in a soft carpet of the same hue, formed by the "wire grass" which abounds throughout this territory.

Will the operator, in the exploitation of these remaining forests, profit by the demonstrated inefficiency of past methods? Can he change his attitude of thought toward the living tree on which his operations are based? Is he willing to place himself in line with all other lines of modern industrial life, which have realized, or are beginning to realize, that true progress in any industry must be based, not upon individual opinion or hereditary teachings, but upon scientific research and constant striving for greater efficiency?

Upon the answer to these questions depends largely the future of the naval-stores industry. This is not a matter for indefinite proceeding along inefficient lines: the actual life of the industry is threatened, for the once-considered inexhaustible forests are rapidly disappearing. At the present rate of destruction the end can be fairly well forecasted, especially since no effort is being made toward reforestation.

It was natural that destructive methods should have characterized this industry, for the early settlers in eastern North Carolina found forests of long-leaf pine everywhere. Clearance was necessary for agriculture, crops had to be grown, lumber was needed for industry, homes had to be built, and so the work of destruction began.

It was immediately recognized that this tree, when wounded, is a prolific producer of an oleoresin, "crude turpentine." Furthermore, the rich resinous wood, when heated out of contact with air by piling in heaps and covering with earth, gave off a rich distillate of tar, which could be boiled down to a pitch. These products, tar and pitch, were much needed for the wooden ships with their extensive rigging, at that time universally in use; and so along with agriculture, with its yearly crops, there developed the naval-stores industry with its constant output of immediately marketable products.

The method of conducting the industry called for no plant other than the forests, and so when the yield of the trees began to decrease after two years of operation, new tracts were opened, and the industry began its march southward, from North Carolina

into South Carolina, thence into Georgia and Florida, and then rapidly expanding into the Gulf States, though on a smaller scale.

In the early days in North Carolina no effort was made to separate the crude turpentine by distillation into its constituents, spirits of turpentine and rosin, the gum being shipped to Northern cities or to England for such manufacture. In the early part of the past century, however, this manufacture was trans-

Timber blown down. Results of severe boxing followed by fire.

ferred to the woods, iron stills being at first employed, which later were replaced by the more efficient copper stills such as are used to-day for this purpose.

In the woods, however, there was no corresponding advance in methods of operation, with the exception of slight improvement in the tools employed. Thus for more than a hundred years the method of wounding the tree and collecting the gum remained the same throughout the turpentine belt.

The normal routine on all turpentine farms consisted of the following operations:

"*Boxing.*"—In the winter negro laborers, under the direction

of a white woodsman, cut "boxes." The box was an elliptical cavity cut in the base of the tree, usually just above the junction of a prominent root with the trunk of the tree. It served to collect the gum which flowed during the warmer months from the scarified surface above. The tool used in cutting this box was a very long, narrow axe, the negroes developing consummate skill in the use of this "box axe." The standard dimensions of the box were 14 inches width, 7 inches depth, and 3½

Tree felled by wind. Result of severe boxing on one side.

inches from the outer wood toward the centre of the tree. The number of boxes per tree was increased from one to four, and occasionally five, according to increasing diameter of the trees.

"*Cornering.*"—Box cutting was followed by "cornering." This consisted of removing two triangular chips from immediately above the box by means of the usual wood-chopping axe. The function of cornering was to provide smooth surfaces to direct the flow of the gum into the box.

"*Chipping.*"—As vegetation became active in early spring the work of scarification of the trunk of the tree began, and con-

tinued weekly for eight months. The repetition of this process was necessary, as the flow of gum, greatest during the first three days following the fresh chipping, practically ceased after one

Round or untapped timber. Long-leaf pine.

week. The tool employed in chipping, called a "hack," was a stout U-shaped steel blade attached by a metal shank to one end of a round wooden handle. This handle carried on its other end a heavy iron weight which gave momentum to the free arm

stroke used to draw the blade through the bark and outer sapwood. A slightly modified form of this tool, called the "puller," was mounted on a much larger handle, with no iron weight attached, and was used for the higher reaches of the third and fourth year of scarification.

"*Dipping.*"—At periods of four to five weeks, when, in the judgment of the woodsman, the boxes showed an average filling, the gum was removed into buckets by a broad, flat, spear-shaped tool, called a "dip spoon." Barrels placed at convenient distances in the woods received the gum from the buckets, and were then hauled to the "still" for distillation.

"*Scraping.*"—As the chipping season progressed not all of the gum found its way to the box, for as crystallization of the gum began some of this mass remained sticking to the exposed surface of the tree. At the close of the chipping season this accumulated resinous mass was scraped from the trees, giving thus the name, "scrape," to the product. Its content of spirits of turpentine was much lower than that of the gum from the boxes.

"*Raking.*"—With the completion of the scraping, the final operation was the protection of the trees from the ground fires which prevail throughout the turpentine belt in late winter when the dead wire grass is burned. Such protection, "raking," was effected by means of a common hoe, all combustible material, chips, pine needles, and dead grass, being removed to a distance of about two feet from the base of the tree.

This completed the year's operations in the woods, and the cycle was then renewed from year to year.

The severe strictures on the wastefulness of the industry spoken by the German technologist, Otto N. Witt, led to the determination on the part of the writer to investigate whether or no this criticism was deserved. Correspondence with men familiar with the industry, and a brief visit to a turpentine farm in South Georgia, afforded ample proof that conditions were even worse than had been depicted.

With such waste prevalent, could not something be done to improve the situation? Here the methods of work learned through research in a chemical laboratory asserted themselves. A search of the literature was begun and made as comprehensive as possible. The result of this study and of observations

in the woods made clear the fact that the great evil of this industry, that which more than all else was responsible for the waste and destruction, was the cutting of the "box" in the base

Cutting the "box." Near Ocilla, Ga.

of the tree. This deep cavity, located just where the strain was greatest, caused many of the trees to fall in even slight windstorms. It constituted a great source of danger during fires, especially after turpentine operations had ceased and the tree

no longer was protected by the annual "raking." The decreased vitality of the tree, due to the severe wound, led in many cases to easy attack by injurious insects. Such evils were easily noticeable, but others, less readily seen, were found upon closer study. With a receptacle at a fixed point, while the distance between the receptacle and the freshly-chipped surface increased regularly from week to week, opportunity was thus afforded for increasing loss of the volatile oil by evaporation, for coloration of the rosin by absorption of oxygen from the air under the influence of sunlight, and for waste in dripping outside the box. It seemed reasonable, moreover, that this severe wound would so decrease the vitality of the tree as to cripple, at least to some extent, the power of the tree to produce crude turpentine. The "box," therefore, should be the primary point of attack in any effort to conserve these forests.

To overcome the evils of the "box," a substitute receptacle must be provided which should inflict but a slight wound in placement on the tree; should be capable of removal at convenient intervals to a point just below the chipping surface; should be extremely simple in its construction, in view of the gummy character of the product it was to receive; easy of operation, because of the unskilled labor which would use it; and cheap, if hopes were to be entertained of its commercial introduction by those who were abundantly satisfied with existing methods and fully convinced that no better could be found—an unfortunate state of mind in these days of progress.

The literature of the French system of turpentining was then studied, and the records of the Patent Office were thoroughly searched. Nothing, however, was found quite free from objections to its ability to meet the above requirements, especially as applied to the system of chipping as practised in the Southern States. In the light gained from this study, however, a substitute was devised, consisting of a simple cup suspended, through a hole near its rim, on a common nail. Into this cup the gum was to be directed by two shallow galvanized iron troughs or gutters, to be inserted about one-quarter inch deep by one of their long edges in correspondingly shallow inclined cuts across the scarified surface of the tree.

With this apparatus provided, and again following the procedure of laboratory research, preliminary experiments were

begun, during the summer vacation of 1901, in the forests of southeast Georgia, near the town of Statesboro, on timber provided, after much persuasion, by some of the leaders of the in-

Cornering the box.

dustry in Savannah, Georgia, who viewed their concessions with an eye of infinite skepticism.

The results of these preliminary experiments were the thorough demonstration of the efficiency of the apparatus, a deeper

grasp of the problem to be solved, a genuine sympathetic interest with the personalities of many employed in the industry, and much knowledge of the habits of the pine. It was completely demonstrated that the dark color of rosin produced under the box system, after the first year of operation, was not at all due to physiological changes in the pine, but solely to the method of collecting the gum. Under this system opportunity was offered for increased oxidation and for absorption of the deeply-colored gum coating the exposed surface, formed by the chipping of previous years. This latter point was important, as the commercial value of the rosin decreases as the depth of color increases.

The United States Bureau of Forestry, hearing of the proposed preliminary experiments, tendered the writer a collaboratorship in order to secure publication of the results. The experiments were so full of promise that it was agreed that the work should be promptly resumed at the opening of the next season, with field experiments on a commercial scale, under the auspices of the Bureau of Forestry. Accordingly the experiments were begun in February, 1902, on the turpentine farm of Powell, Bullard & Company, a well-known firm operating in southeast Georgia, near the town of Ocilla.

For these experiments the following policy was adopted at the outset:

First, the timber was to be provided by the firm; the cups and gutters and cost of installation, by the Bureau.

Second, the labor was to be none other than such as was employed in the regular work of the farm.

Third, the experiments were to be restricted solely to the "box" question and the practicability of the substitute cup and gutters. Therefore the work of chipping, dipping, and scraping should be conducted in the normal way.

Fourth, four sets of comparative experiments were to be conducted simultaneously, one on virgin timber, and three on boxed timber which had already been operated respectively one, two, and three years. This would determine, so far as possible in one year, the influence of the box on the timber and on the income of the operator.

Fifth, the results should be taken from the records of the company, whose statements would be readily accepted by all other operators.

So far, so good. Then troubles began. The manufacturer, delayed in his work, did not deliver the equipment until the chipping season was nearly at hand. This led to shortcomings, un-

Chipping the first "streak" above the virgin box.

dreamed of at the time, and which in after-years caused the loss of many thousands of dollars; but this will be discussed later. Next, labor troubles were unexpectedly encountered. The negro laborer proved even more conservative than the white operator

and woodsman, and assumed the remarkable attitude that the "flower-pot" method of making turpentine was more properly the work of women and children, and not suited to the dignity of full-grown men. This may be difficult of belief, and it was strange in the light of later developments, but it proved a serious obstacle for some time. By dint of patience, tact, and kindly reasoning this trouble was at last overcome sufficiently to enable a beginning of work in the woods with three laborers, but up to the very moment of actual handling of the axe the chagrin and mortification of those three negroes, too inefficient for the regular box-cutting squad, were comical, though the situation had its serious side in that the whole question of the carrying out of the experiments was at stake in the successful solution of this labor difficulty. It is sufficient here to state that in a short while the problem was completely solved, and as success in the experiments became more and more marked the comical picture then became the rather haughty air and proud demeanor of those who gleefully dubbed themselves "cup niggers!"

To return to the experiments: three crops were selected, consisting each of 10,000 boxes, the unit of operation. These three had already been under operation one, two, and three years respectively. On one half of each of these crops cups and gutters were installed near the point where the chipping would begin. On the other half the gum was collected in the normal way, in the box, at the base of the tree. These experiments would determine the practicability of the equipment at varying heights on the tree; the quality, as to color, of the rosin produced from gum collected under the two systems; and would give some information as to relative waste from evaporation, etc.

The main interest, however, centred in the experiment on virgin timber, where the two systems could be put into operation under fully equal conditions. For this experiment a tract of timber of fair average quality was selected by the firm just outside of the town. To insure accuracy of the experiment, this timber was carefully and repeatedly cruised by experienced woodsmen, and a division made as to location of cups and boxes respectively. In this division it was decided to alternate the "drifts" (subdivisions of a crop) of cups and of boxes. This also furnished more uniform weather conditions in working the two halves. The entire crop was to be chipped by one man, and the

dipping was to proceed every three weeks simultaneously in the cupped and boxed halves of the crop, the gum to be collected in different sets of barrels. The presence of varying amounts of

Gutters and cup in position.

trash and water would render inaccurate the results from measuring or weighing the gum. Therefore it was distilled and record kept of the number of gallons of spirits of turpentine obtained from each lot, and separate sales made of the rosin produced.

No difference in quality of rosin was expected or found here. As the distance of flow of the gum was the same in each set, loss of spirits of turpentine by evaporation was equalized. All precautions were taken so that whatever difference of results might be found in the yields from the two halves could be as-

Unboxed tree with cup and gutter in position at end of first year's chipping, showing correct position. Ocilla, Ga.

cribed to no other factor than the influence of the severe wound caused by box cutting on the productive power of the trees. The advancement of the idea that it decreased productive capacity had met with hoots and jeers on all sides; and here in this crop, it was felt and stated without the least effort of repression. would be demonstrated the superiority of the judgment of the "practical" man over the theoretical college professor.

The work of installation began. Two flat faces meeting in a central line were cut with common axes to adapt the round tree to the straight-edged gutters, two laborers with broadaxes made across these plane surfaces the incisions for the gutters, which were promptly inserted by another group of laborers, the upper gutter reaching just to the centre of the face and emptying into the opposite gutter equally inclined, running about one inch lower and extending about two inches beyond the angular centre of the face, to provide a suitable hanging of the cup into which all of the gum dripped. While awaiting the arrival of the cups and gutters, the box-cutting squad and the "cornerers" had been gleefully at work in the other half of the crop.

With the respective receptacles provided and installed, the work of chipping began—and the race was on. The detailed results are given in Table 1.[1]

TABLE 1.

First-year Crop—Dippings.

Number of dipping	Date of dipping		Number of chippings	Barrels of dip obtained		Spirits of turpentine on distillation (gallons)		Excess spirits of turpentine (gallons)	
				Boxes	Cups	Boxes	Cups	Boxes	Cups
1........	April	14	3	*9¾	†7⅜	101.6	84.3	17.3	....
2........	May	5	3	9¼	10⅞	111.0	130.5	....	19.5
3........	May	26	3	12	14½	136.8	178.3	....	41.5
4........	June	16	3	12½	17⅛	143.3	191.2	....	47.9
5........	July	7	3	12¼	14¾	142.4	175.2	....	32.8
6........	July	28	3	10½	12¾	115.2	141.7	....	26.5
7........	August	18	3	10	11¾	106.6	126.6	....	20.0
8........	September	8	3	8	10¼	86.1	105.9	....	19.8
9........	September	29	3	7⅜	9½	80.8	106.0	....	25.2
10........	November	4	5	‡10¼	12¾	110.9	145.6	....	34.7
Total...	....		32	101⅞	121⅝	1,134.7	1,385.3	17.3	267.9

* Including resin from box cutting and cornering.
† Including resin from placing cups on trees.
‡ Boxes dipped after trees have been scraped.

The unexpected shortage from the cups on the first dipping led to great rejoicing among the box supporters, and to undoubted apprehension on the part of the solitary backer of the cups. The second dipping, however, altered the situation, and by the last of June the victory for the cups was so complete that all were

[1] The tables throughout this paper are from Bulletins 40 and 90 and Circular 34 of the United States Forest Service.

converted. The beginning of the end of the box system had been reached. From this point on all went well. Labor was anxious to enlist, enthusiasm had supplanted scoffing, and now the chief effort of the original cup backer was to guard against possible inflated results, due to some over-zealous convert, which results might not be justified by the facts in the case, for in spite of convictions formed in advance of experiment it was, as in all research, the truth which was sought.

Several years passed, much thought was expended, and many experiments were made before the true interpretation of that shortage on the first dipping was obtained and its remedy provided. This will be discussed later.

Meanwhile the distillation of the gum from the second-, third-, and fourth-year crops showed uniformly high-grade rosin from the cups, as contrasted with the low-grade rosin from the corresponding boxes, and the equipment proved itself readily adaptable to the increasing heights of chipping.

The results of net rosin sales from all four crops are given in Table 2.

TABLE 2.

Season's Record of Net Rosin Sales.

Half crop	From dip	From scrape	Total	Excess net sales	Per cent. excess net sales, cupped trees
First year:					
Cups	$401.72	$47.72	$449.44	$85.51	23.50
Boxes	328.40	35.53	363.93	......	......
Second year:					
Cups	266.34	49.25	315.59	144.13	84.64
Boxes	104.51	66.95	171.46	......	......
Third year:					
Cups	171.27	27.44	198.71	132.65	200.80
Boxes	39.49	26.57	66.06	......	......
Fourth year:					
Cups	167.33	29.23	196.56	132.56	207.13
Boxes	36.09	27.91	64.00	......	......

The experiments with the second-, third-, and fourth-year crops were discontinued at the end of the year, having served their purpose. The working of the virgin crop, however, was continued two years longer. The complete results for the three years' operation of this crop are given in Tables 3, 4, and 5.

TABLE 3.

Spirits of Turpentine from Half Crops.

Year	Cups			Boxes			Excess from cupped half crop	Net price per gallon at time of operation	Value of cup excess
	From dip	From scrape	Total	From dip	From scrape	Total			
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Cents*	
First......	1,385.3	205.0	1,590.3	1,134.7	153.7	1,288.4	301.9	40	$120.76
Second....	1,103.5	165.0	1,268.5	705.2	226.6	931.8	336.7	45	151.52
Third.....	781.3	136.0	917.3	536.1	190.5	726.6	190.7	45	85.82
Total...	3,270.1	506.0	3,776.1	2,376.0	570.8	2,946.8	829.3	..	358.10

TABLE 4.

Net Sales of Rosin from Half Crops.

Year	Cups			Boxes			Excess from cupped half crop
	From dip	From scrape	Total	From dip	From scrape	Total	
First..............	$401.72	$47.72	$449.44	$328.40	$35.53	$363.93	$85.51
Second.............	286.88	58.24	345.12	132.42	84.08	216.50	128.62
Third..............	212.60	61.65	274.25	124.76	79.70	204.46	69.79
Total..........	901.20	167.61	1,068.81	585.58	199.31	784.89	283.92

TABLE 5.

Summary of Gain from Cupped Half Crops.

Years	Spirits of turpentine	Rosin	Total
First....................	$120.76	$85.51	$206.27
Second...................	151.52	128.62	280.14
Third....................	85.82	69.79	155.61
Total...............	358.10	283.92	642.02

Total Value of Products from Three Years of Operation.

Cupped half crop............................ $2,688.55
Boxed half crop............................ 2,046.53

Gain from cupped half crop............... 642.02 = $1,284.04 per crop.

That the distribution of the timber in this virgin crop had been well equalized was shown by measurements of diameters of all trees in the crop and by a determination of the average number of cups or boxes per tree throughout the crop.

As the work progressed, careful record of the dead and down trees were made in each half. The count at the end of the three-year period is shown in Table 6.

TABLE 6.

Record of Down and of Dead Trees.

	Number of trees blown down		Number of trees dead	
	Boxed	Cupped	Boxed	Cupped
In 1 year.........	8	3	35	16
In 2 years........	60	34	139	83
In 3 years........	78	44	217	150

During the chipping season portions of some of the chipped surfaces became unproductive, locally termed "dry face." The results of the measurement of the extent of "dry face" in the two halves of the crop showed an excessive amount in the boxed half at the end of the first year. From that time on the amounts, while increasing in each, showed less striking difference. Evidently the cause of increased "dry face" in the last two years lay more and more in the chipping, and this observation led to later valuable experiments on comparative yields from lighter chipping.

The results of the first year's experiments were communicated to the turpentine operators at their annual convention. Much interest was aroused and some enthusiasm. The next few months, however, proved an interesting testimonial to the "follow-up" policy of the wise advertiser, for, in the three-month period spent in arranging for the manufacture of the equipment at a reasonable cost and in the preparation of an account of the experiments for publication as a government bulletin, interest in the matter completely disappeared. It was only through the most persistent efforts that interest was sufficiently re-aroused, in those at one time enthusiastic, to assure the commercial utilization of the rather limited output of the cup factory.

This first season's use of cups by the operators assured the future, the results obtained more than confirming the experimental results of the previous year. Instantly the demand increased; prejudice slowly gave way; the quality of the cups was improved with increasing experience at the factory; timber

owners made concessions on price of leases, provided cups instead of boxes, eventually stipulating that timber could not be worked if box cutting was the intention; and labor throughout

"Dipping" the cup.

the territory became familiar with and enthusiastic about the new method. Thus was the box system, with its attendant losses, replaced by the more efficient cup system. To-day box cutting is practically a thing of the past, while many forms of cups, to

suit individual requirements, have become every-day articles of commerce.

From the outset, railway officials of the Southern States, keenly alive to the welfare of the territory tributary to their lines, were strongly sympathetic with this movement, and by their prompt and intelligent handling of the question of freight rates on the equipment facilitated greatly the universal introduction of the new method.

To encourage the adoption of the new system, the Forest Service adopted the wise policy of offering, free of cost to the operators, the services of the writer in inaugurating the work on a turpentine farm. Never to be forgotten was the first experience in this work of instruction, when on a cold, drizzly February day, at a South Georgia saw-mill, there was handed over for instruction a group of sixteen young negro convicts, in characteristic garb and utterly devoid of any knowledge of turpentine operations. The situation seemed impossible and hopeless, but the future of the work was at stake. Fortunately experience gained in years of teaching in the class-room came to aid. The setting was entirely changed, but the methods of pedagogy were applicable and necessary. The effort succeeded. After such an experience all others were easy.

The "practical man," however, had his inning, for a little later, working in timber near the Gulf Coast of Florida, it was found that such timber was so tough that it was impossible to make smooth, flat faces on the tree for the gutters with the ordinary axe employed. After a long day of struggle, with defeat clearly ahead, the turpentine operator suggested the use of the broadaxe for this purpose. The experiment was tried and immediately succeeded. Later another step forward was taken by the suggestion of another operator that in hewing with the broadaxe the bevelled side of the edge be placed next to the tree. This was revolutionary from an axeman's point of view, but it was tried and its advantages were immediately noted, for there was no difficulty in forcing the axe to the surface at the base of the cut, thus saving the tree much useless wounding and so increasing the speed of operations that in a little while it was possible, with an equal force of laborers, to install three crops of cups while one crop of boxes was being cut. Such details may appear trivial, yet each had its influence on the rapid introduction of the system.

As reports began to arrive concerning commercial experiences with the system all agreed on increased yield, but all agreed likewise on the unusually large number of chippings required to fill the cups with gum at the beginning of the season, especially

Third-year boxed timber with cup system.

when compared with boxes on similar timber near the cupped trees, the capacity of cup and box being the same. After this first dipping the superiority of the cup system readily showed itself in largely-increased yields. Here was a recurrence of the mortifying experience with the first dipping of the virgin

crop in the experiment at Ocilla. What could be its explanation? How could the trouble be overcome? Various suggestions were made and numerous experiments tried by men of all types in all sections, but without success in overcoming this chief defect in the system.

A few years later the writer had opportunity to visit Professor A. Tschirch in his laboratory at Berne, Switzerland, and there learned his views concerning resin flow, views based on the results of experiments on many pines in the neighborhood. According to Tschirch the resin ducts, found scattered throughout the wood of a normal pine, contain a resin which is formed as a result of natural life processes in the living tree. Such a product is, therefore, a purely physiological product, and such ducts he designated "primary resin ducts." These yield only a small quantity of crude turpentine when the tree is wounded. Immediately after the wounding, however, there begins in the outer fresh wood the formation of a very large number of resin ducts, both above and below the wound, forming an anastomotic system, which pour out crude turpentine in great quantity as a healing balsam over the wound. Such an exudate is a pathological product, and the ducts producing it he termed "secondary resin ducts." These extend four to five inches above the wound, requiring four to five weeks for their full development.

In the light of this knowledge the explanation of the excess yield of the boxes over the cups on the first dipping was simple. When the boxes were cornered a full-width, V-shaped surface was formed above which the secondary resin ducts formed in abundance during the several weeks which elapsed before the chipping season began. Then when the first chipping was made the cut traversed secondary resin ducts along its full length and a maximum yield was obtained. On the other hand, the late arrival of the cups for the experimental work made it necessary to begin chipping immediately afterward. The secondary resin ducts had not fully formed during this brief interval, and there was a correspondingly low yield of crude turpentine, which, however, rapidly increased later as the ducts increased. Again, in explanation of the same difficulty experienced by operators who placed their cups on the trees many weeks in advance of the chipping season, it must be remembered that the flat faces for the gutters were then being made on the tree by the broadaxe. The cutting

of a straight-edged tool into a round tree exposed the fresh wood above in the form of two curved lines, meeting at the centre of the cut surface. Again, the secondary resin ducts formed, but

Removing "scrape" (hard resin) at end of second-year box.

following the outline of the cut. When, therefore, these trees were chipped only about half of these ducts, those near the centre, were traversed by the downwardly-inclined stroke of the hack. Hence a flow of gum far below that in the box system, but again

rapidly increasing after the first full-width cut formed by the first chipping. This suggested a simple method for overcoming the losses encountered during the first six or eight weeks of operating under the cup system; namely, the placing of the gutters on the trees in winter should be followed immediately by one full-width chipping and the trees allowed to stand, without further chipping, four or five weeks. Opportunity would thus be given for full formation of the secondary resin ducts along the full width of the chipping surface, as in the box system.

These views were laid before a number of operators using the cup system, and they were requested to try the modified method on some of their timber during the next winter. They agreed: the experiments were carried out, and in every case the cure for the evil was found to be complete, cups so placed yielding a greater amount on the first dipping than boxes or than cups placed without the one winter chipping. Conservative estimates made by experienced operators place the total annual gain from this slight modification of woods practice at not less than $500,000. Could there be asked a better illustration of the value of pure university research, as was that of Tschirch, for efficient industrial operation?

With the future of the cup system assured, attention was next turned to the relative yield of crude turpentine with reduced wounding of the tree in chipping. These experiments were conducted near Green Cove Springs, Florida.

In order to interpret the results clearly, all trees were cupped, and one of the crops chipped to normal depth, seven-tenths of an inch into the new wood, the thickness of the chip being such as to carry the chipping up the trunk at the normal rate. This crop was designated A.

In another crop, designated B, the depth of the chipping was reduced from seven-tenths to four-tenths of an inch, all other conditions being identical with the standard crop, A.

In a third crop, designated C, the thickness of the chip was so reduced that the same elevation on the trunk would be reached in four years as was reached in three years in crop A, all other conditions being alike in the two crops.

Finally, in a fourth crop, designated D, no tree under ten inches was worked; the minimum diameter for trees bearing two cups was raised from twelve inches, as in crop A, to sixteen

inches; and, finally, no tree bore more than two cups, regardless of its larger diameter. In this crop the chipping was the same as in the standard crop, A.

The results of the four years of work on these crops are given in Table 7.

TABLE 7.

Crop	Dip		Scrape		
	Yield	Increase	Yield	Increase	Decrease
	Pounds	*Per cent.*	*Pounds*	*Per cent.*	*Per cent.*
A	206,235	.....	47,742	.....	.....
B	211,911	2.75	44,838	.....	6.08
C	214.503	4.01	39.775	.....	16.69
D	279.260	35.41	53,915	12.93	.....

The marked success of these experiments led to a further experiment for one year, in which was compared with a standard crop, such as A above, the yield from two crops, designated G and H, in which both modifications of chipping, shallow and thinner cuts, as in B and C above, were combined. The results are given in Table 8.

TABLE 8.

Crop	Number of cups	Number of chippings	Yield of dip	Increase
			Pounds	*Per cent.*
Walkill Turpentine Company	9,880	35	90,094	..
G	9,880	35	124,292	38
H	9,880	35	121,474	35

Thus was the way clearly pointed out for more conservative treatment of the trees, the result being largely-increased yields.

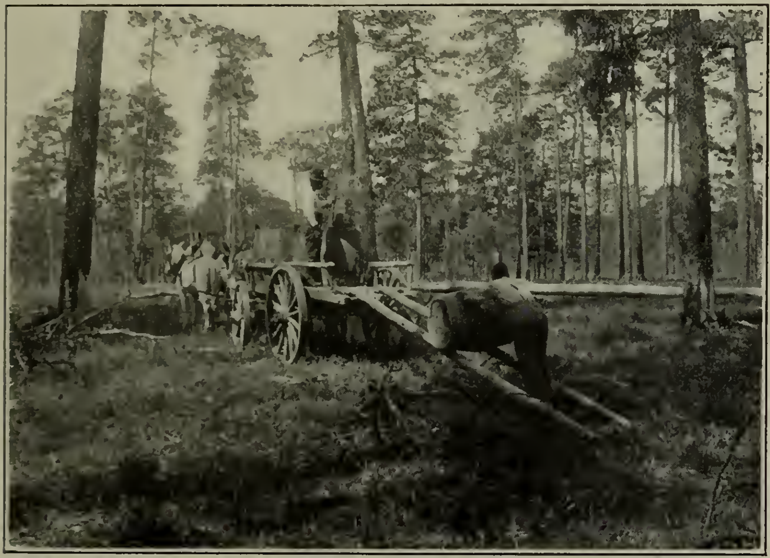
Are further experiments on the reduction of the wound in chipping justified? This is a difficult question to attempt to answer. Certainly there is a limit to which such reductions can be carried, beyond which financial loss will result, under existing conditions of cost of stumpage and wages of labor. If the tree is not wounded, crude turpentine is not produced; if it is girdled, the tree dies. Somewhere between these extremes lies the most efficient operation. From the results already mentioned it is evident that past practice in chipping has been on the side of too

excessive wounding. Whether or no the limit should be further reduced can be determined only by experiment.

One abuse, however, has arisen in connection with the spread of the cup system; namely, the general practice of cupping very small trees. Such trees were not brought into operation under the box system, as they were too small to receive a box, but they could be cupped with ease. Two strong objections hold against this practice. *First,* the trees of the future naval-stores industry are being destroyed, a well-marked case of child-labor abuse for which there is no legislative correction. *Second,* the judgments of the leaders of the industry agree that the operation of such small trees is unremunerative in itself, yet often producing sufficient crude turpentine to seriously depreciate the market value of that produced from the larger trees. Much has been spoken and written by these leaders against the practice, but still it continues. Is not experiment advisable here? The following is suggested, and it is hoped that the suggestion will receive the consideration of the United States Forest Service. An investigation is needed of what is the actual yield from a crop of ten thousand of these very small trees during a period of three or, better, four years of operation. Such an investigation would give facts where now mere opinion prevails. The experiment would not be costly, because it could be carried out in connection with the regular operations of a turpentine farm. It would require only efficient supervision; the dipping from the small trees to be kept separate from those of unquestioned size, say ten inches and over in diameter; the yields from the two lots compared, and the results published for the benefit of all. Such a publication would constitute a valuable contribution to the literature of this subject, and such facts would carry far more weight than any amount of spoken or published criticism.

Leaving now questions connected with woods-practice, let us follow the barrels of gum to the distillery, or "still," as it is uniformly called. This manufacturing plant is exceedingly simple, and, as a rule, roughly built, the rapidly-shifting character of the industry not justifying more pretentious housing. A large copper kettle, the "still" proper, is set in brick masonry above a fire-box in which pine wood is burned. Eight to ten barrels of the gum, mixed with chips, dirt, and some water, constitute a charge, the distillation of which requires from three to four hours. The

kettle is connected by a removable "still head" to a coiled copper worm, set within a large wooden tank, the condenser, into which cold water flows or is pumped at the bottom, cooling thus the hot mixed vapors of steam and spirits of turpentine in the condenser coil. The heated water is led off by an overflow or is partly used by running along a narrow trough leading from the top of the condenser to a small, funnel-shaped opening in the lower part of the still head, and emptying into the still and on to the boiling gum below, the steam thus generated aiding materially



Hauling crude resin from the turpentine orchard to the still.

the separation of the volatile spirits of turpentine from the non-volatile rosin. The proper regulation of this flow of water has been generally determined by the sound produced by the boiling mass heard at the mouth of the condenser. Recently the use of inset thermometers for the purpose of controlling the distillation has largely increased. The condensed liquids, flowing from the mouth of the worm, separate at once in the receiving vessel into two layers. The lighter spirits of turpentine is pumped into large storage tanks or is dipped into oak barrels, which have been thoroughly coated inside with glue. It is now ready for marketing. When the volatile oil is practically all removed, the still head

is taken off, and the chips are skimmed. In the case of virgin dip this skimming is done as soon as the gum melts and before distillation begins. Finally, when all water has boiled off, a necessary precaution to prevent the rosin being opaque, the molten rosin is allowed to flow from the still through a tail pipe, leading from the bottom of the still, to two strainers placed the one above the other. The upper strainer consists of coarse wire gauze, and retains unskimmed chips. The lower strainer, of fine brass gauze over which are placed layers of cotton batting,

Turpentine still. Ocilla, Ga.

retains the dirt and smaller portions of trash. From these strainers the rosin flows into a long wooden vat, from which it is promptly dipped into barrels, where, upon cooling, it solidifies and is then ready for shipment.

Crude as the method appears to the casual observer, nevertheless careful study of this system as compared with the much more expensive systems in France has convinced the writer that, given a good stiller, equally good results are obtained by this very inexpensive outfit. Of course, the presence of the personal element, as represented by the stiller, is always a risk in manufactur-

ing operations, and it would seem to be a needless risk in the light of its complete elimination in the French system of "mixed injection," where heating is effected partly by free flame and partly by steam; where water vapor is furnished both by inflowing hot water and by direct injection of steam; and where operations are controlled entirely by the thermometer. Such plants are not expensive and are very simple in operation.

The suggestion has recently been made that this industry would be placed on a much more efficient basis if the smaller stills in the woods were done away with, the gum hauled in tank cars direct to a central distillery, advantageously located, and there distilled. This suggestion contains many thoughts which justify the belief that here lies the way to the next decided step forward in the evolution of this industry, if questions connected with transportation can be properly worked out. Undoubtedly there is much waste at the present small distilleries. Important matters concerning utilization of by-products cannot be properly handled under the present system. Much demoralization of labor arises from the still being near the turpentine camp. On the other hand, the handling of crude turpentine in sufficient quantities at a central distillery would justify the presence of the most efficient forms of stills and of labor-saving devices common to all handling of material in large quantities. Of possibly still greater importance is the fact that operations on such a scale would justify the employment of competent chemists, who, in addition to the careful control of the operation of the distillery, could supervise the manufacture of rosin oil directly from the molten rosin, of the various commercial articles into which such products enter, and who could by systematic research find new uses for and new transformations of the various products, thus guiding the industry to wider fields of application, and enabling it to more fully keep abreast of that progress characteristic of all industries which wisely make use of the services of well-trained chemists.

Wind-deflecting Mask for the Use of Locomotive Engineers. ANON. (*Scientific American,* vol. cxiv, No. 3, January 15, 1916.)—A few years ago an engineer on a Canadian railroad was tried for killing several passengers as a result of a rear-end collision between his engine and a passenger train ahead. His defence was simply that the weather was 40° below zero, a 40-mile wind was blowing, the severity of which was greatly increased by the speed of his train, and it was a human impossibility to withstand the cold long enough to get even a glimpse ahead from the open window. The other windows were so incrusted with ice that they might as well have been solid walls, for all that could be seen through them.

The engineer won his case on the strength of his testimony, but as a result of the case a mask was invented which eliminates the discomforts of looking forward in bitter cold weather and gives the engineer a clear and unobstructed vision, without even glass intervening. The result is secured by deflecting the air currents downward as they enter the mask, and by forming a suction or draft at the bottom all air is drawn away from the engineer's face. So perfect are the results secured that a match held at the back of the shield burns steadily. The space between the deflecting partitions at the top and those at the bottom of the mask is open, and it is through this space that the engineer secures a clear view of the track ahead. The device is being generally adopted by the Canadian railroads as a safety measure and for the greater comfort of their enginemen.

Newly-invented Circular Computer of Marked Accuracy. ANON. (*Scientific American,* vol. cxiv, No. 3, January 15, 1916.)—In an endeavor to provide a computer of great accuracy for the use of engineers, Louis Ross, a civil engineer of San Francisco, has devised a new instrument that is at once compact, simple, inexpensive, and, most important of all, has an accuracy equivalent to a slide-rule 100 feet long. The new computer consists essentially of a graduated dial rotating under a slotted cover, a floating guide, and a slide mounted at the right of the slot. The dial carries a scale of numbers reading to five significant figures throughout. The slide carries a miniature of the dial scale reading to three figures. It coöperates with the dial, checks and points out the precise answer and locates the decimal point. For instant or approximate results the slide alone may be used.

The variable graduations of the ordinary slide-rule are replaced by uniform graduations along a spiral curve so proportioned that the angular motion of the index represents the logarithm of the scale reading. The length of the scale, according to the inventor, is 120 times as great as the A and B scales in the ordinary 10-inch slide-rule, although the instrument is only 8 inches in diameter. The new computer is made of metal throughout, and the graduations are engraved on silvered metal surfaces. It is slightly over 8 inches in diameter and weighs less than one pound.

THE THEORY OF SOME VARIABLE NEUTRAL TINT-ABSORBING SCREENS.*

BY

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One of the most important and frequently-occurring problems in the design and use of optical and photometrical apparatus is how best to vary the intensity of a light flux easily and at the will of the operator. Many different solutions to this problem have been devised, a list of which need not be given here. It is the purpose of this paper to collect for record some incidental work, extending over the past two years, on some neutral tint-absorbing screens made for this purpose.

The three screens that have been studied are (1) the opaque line grating.[1] (2) the perforated opaque plate, and (3) the parallel wire grating. In the following work a parallel light flux is always assumed.

The first screen was made by ruling two gratings on glass with about 24 black lines per centimetre, then placing the two gratings and the lines parallel and slightly separated.[1] When this screen is rotated about an axis parallel to the lines, the transmission varies at a rate determined by the separation of the surfaces. Part of a section perpendicular to the lines is shown in Fig. 1. The lines are shown staggered and not exactly opposite one another, the angle of staggering being denoted by ϕ as indicated. The angle of rotation is called θ and is taken positive for counter-clockwise rotation, being equal to zero when the surfaces of the screen are normal to the light flux.

For this screen we have, using the symbols of the figure,

$$X = (S - S_1 + S_2) \cos \theta \text{ where} \qquad (1)$$
$$S_1 = T \tan \phi \text{ and}$$
$$S_2 = T \tan \theta$$

(1) becomes

$$X = (S - T \tan \phi + T \tan \theta) \cos \theta \qquad (2)$$

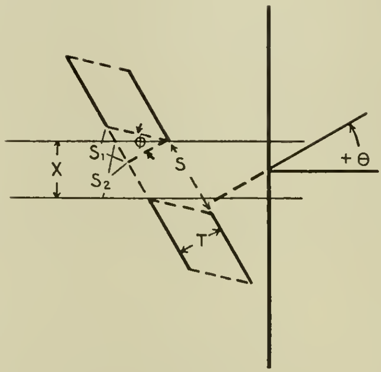
* Communicated by the Author.

We will now express (2) in terms of the maximum transmission as unity. The light flux passing through unit area of the screen when normal to the flux is proportional to the total open area, which equals the number of openings, n, per unit area, times the area of each, X, multiplied by the other dimension, a, thus: open area $= n\,X\,a$.

Now at any other angle, θ, to the normal the number of openings exposed to this same flux is $n \sec\theta$ and their open area

$$n\,X\,a \sec\theta$$

Fig. 1



Part of a section of the opaque line grating perpendicular to the rulings.

The maximum value of X is $S \cos\theta$, and the maximum area $nSa \cos\theta$ times $\sec\theta$.

The transmission then becomes

$$\frac{n\,X\,a \sec\theta}{nSa} = \frac{X \sec\theta}{S}$$

Multiplying (2) by $\frac{\sec\theta}{S}$, we get

$$\text{Transmission} = 1 - \frac{T}{S}\tan\Phi + \frac{T}{S}\tan\theta \tag{3}$$

This holds for all values of θ taking θ + or − on opposite sides of zero. For $\theta > \Phi$ after (3) has passed through a maximum (3) changes to

$$\text{Transmission} = 1 + \frac{T}{S}\tan\Phi - \frac{T}{S}\tan\theta \tag{4}$$

There is also a similar pair of equations representing a second case where the screen as shown in Fig. 1 is rotated 180° through a plane perpendicular to the paper, the corresponding equations becoming

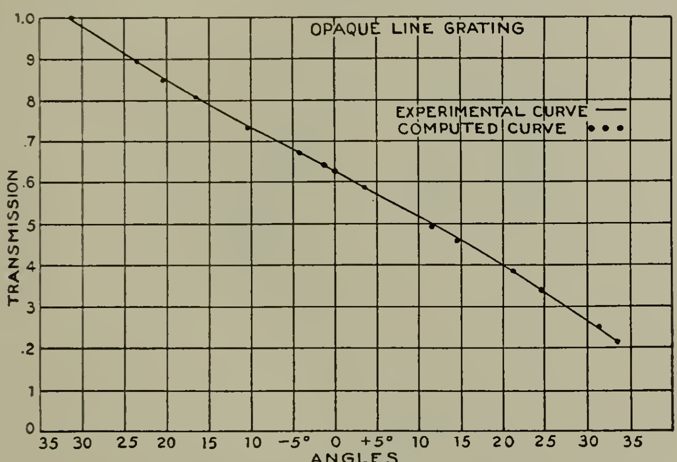
$$\text{Transmission} = 1 - \frac{T}{S}\tan\Phi - \frac{T}{S}\tan\Theta \qquad (5)$$

and for $\Theta > \Phi$ through a maximum

$$\text{Transmission} = 1 + \frac{T}{S}\tan\Phi + \frac{T}{S}\tan\Theta \qquad (6)$$

Fig. 2 shows in the solid line the calibration curve of such a screen when the staggering is of the second case, making (5) ap-

FIG. 2.



An experimental and theoretical calibration curve of the opaque line grating.

plicable. The calibration could not be extended to show the equivalent of (6) also. The equation fitting this curve is

$$\text{Transmission} = 0.623 - 0.620 \tan\theta \qquad (7)$$

and the computed points are shown as dots in Fig. 2. (7) in the form of (5) is

$$1 - 0.620 \tan 31^\circ\, 18' - 0.620 \tan\theta \qquad (8)$$

This curve has the desirable characteristic of passing through a point of inflexion which makes it approximately linear through that region.

The second grating studied was a brass plate drilled as closely as possible. Fig. 3 shows a section of one hole and also a perspective view of the same from one side. We have

$$Z_1 + Z = 2R \cos \theta \qquad (9)$$

$$\text{where } Z_1 = T \sin \theta \text{ and}$$

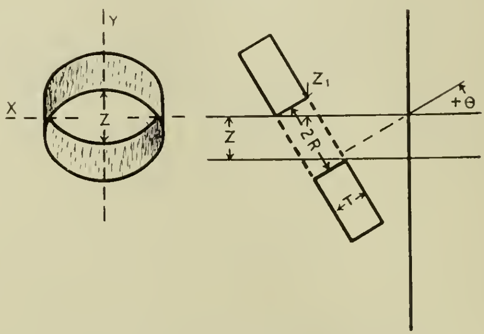
$$Z = 2R \cos \theta - T \sin \Theta \qquad (10)$$

As the plate is tipped from the normal to the light flux the equation for each apparent ellipse is

$$\frac{X^2}{R^2} + \frac{Y^2}{(R \cos \Theta)^2} = 1 \qquad (11)$$

$$X = \pm \frac{\sqrt{(R \cos \Theta)^2 - Y^2}}{\cos \Theta} \qquad (12)$$

FIG. 3.



An opening of the drilled metal plate screen.

For area of one opening take

$$A = 4 \int X \, dy$$

between the limits of

$$Y = R \cos \Theta$$

$$Y = R \cos \theta - \frac{Z}{2} = \frac{T}{2} \sin \Theta$$

$$A = \frac{4}{\cos \Theta} \int_{\frac{T}{2} \sin \Theta}^{R \cos \Theta} \sqrt{(R \cos \Theta)^2 - Y^2} \, dy \qquad (13)$$

$$A = R^2 \cos \Theta \left[\pi - 2 \sin^{-1} \left(\frac{T}{2R} \tan \Theta \right) \right] - TR \sin \Theta \sqrt{1 - \left(\frac{T}{2R} \tan \Theta \right)^2} \qquad (14)$$

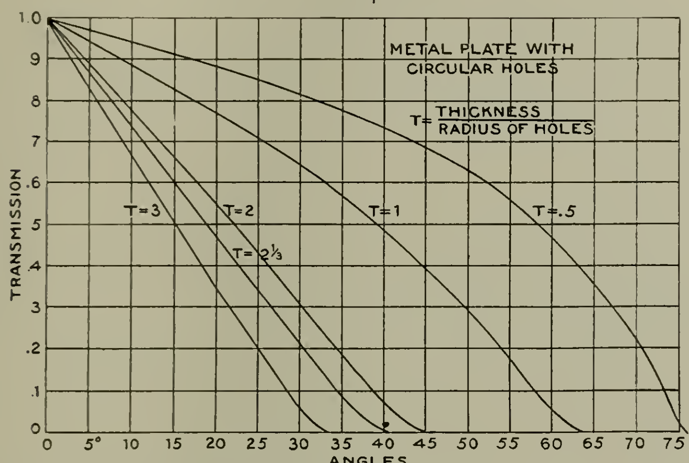
We will consider T as measured in terms of R, which will be taken as unity. The total transmission will be as above, equal to the open area nA, subtending per unit normal area. At $\theta = 0$ this open area is $n\pi R^2$ and at θ, $nA \sec \theta$, therefore for maximum transmission unity we have

$$\frac{nA \sec \Theta}{n\pi R^2} = \frac{A \sec \Theta}{\pi} \quad \text{where } R = 1.$$

Multiplying (14) by $\frac{\sec \Theta}{\pi}$ it becomes:

$$\text{Transmission} = 1 - \frac{2}{\pi} \sin^{-1}\left(\frac{T}{2} \tan \Theta\right) - \frac{T}{\pi} \tan \Theta \sqrt{1 - \left(\frac{T}{2} \tan \Theta\right)^2} \quad (15)$$

FIG. 4.



Theoretical calibration curves for the drilled metal plate for various ratios of thickness to radii of the holes.

Fig. 4 shows five curves plotted according to (15) for $T = 0.5$, 1, 2, 2⅓, and 3 respectively. They are interesting as showing how the curves pass through practically a straight line for $T = 2⅓$, the only sharp bend being a short one at the lower end.

The third and last screen studied was the parallel wire grating, a part of a section of which is shown in Fig. 5.[2] A rigid metal frame was wound uniformly and tightly with a soft iron wire. The portions of the wires that bend over the edges of the frame were then soldered and all the wire on one side of the frame was then cut away, leaving the other half intact. The

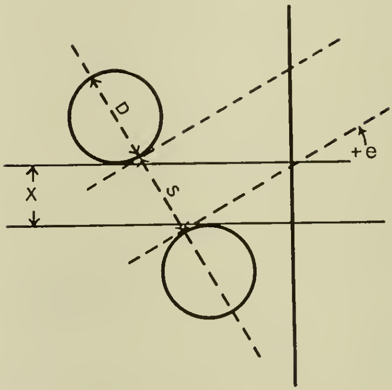
frame was then mounted so as to turn on an axis parallel to the wires.

For this screen we have

$$\frac{D+X}{D+S} = \cos\Theta, \text{ whence} \tag{16}$$

$$X = (D+S)\cos\Theta - D \tag{17}$$

FIG. 5.



An opening of the parallel wire grating perpendicular to the wires.

Following the same reasoning as with the first screen, the transmission with maximum unity becomes

$$\frac{nxa\sec\Theta}{nSa} = \frac{x\sec\Theta}{S} \text{ and multiplying (17) by } \frac{\sec\Theta}{S} \text{ we get}$$

$$\text{Transmission} = 1 - \frac{D}{S}(\sec\Theta - 1) \text{ or} \tag{18}$$

$$\text{Transmission} = 1 - \frac{D}{S} \text{ external } \sec\Theta \tag{19}$$

Fig. 6 shows in the solid line a portion of a curve experimentally determined, and the heavy dotted line the computed according to equation (19) in the following form:

$$\text{Transmission} = 1 - 0.600 \text{ external } \sec\Theta \tag{20}$$

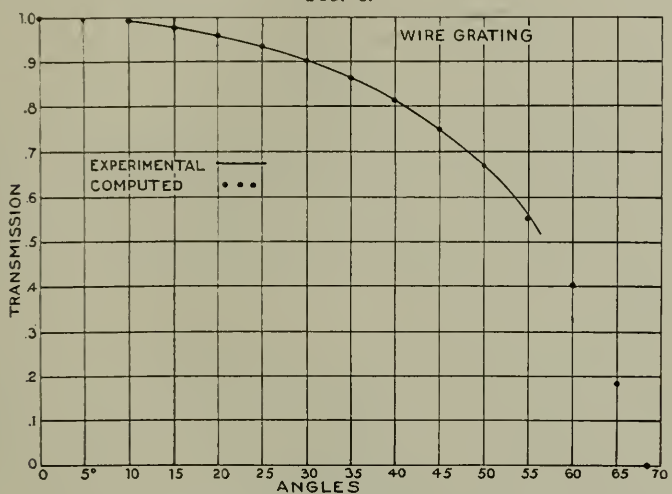
It will be seen that the agreement is excellent. This screen, while very simple from a mechanical point of view, is not so desirable from a theoretical viewpoint, as the curve bends so rapidly. Great care must be exercised in handling this screen, as a slight knock on the wires will easily bend them, changing the calibration. The wires must also be well blackened to avoid reflections.

A careful test was made with this screen to see if a lack of

parallelism of the light flux would alter the calibration over the range shown. As wide a deviation as would likely be met in practice was tried and did not alter the above curve.

The above curves are not intended to take the place of an arbitrary calibration of each screen when put into use, but it is frequently of considerable aid in such a calibration to know in advance what sort of a curve to expect. Therefore it is hoped the above may be of assistance to anyone using these screens in the future.

FIG. 6.



An experimental and theoretical calibration curve for the parallel wire grating.

The thanks of the author are due to Dr. H. E. Ives and Dr. Enoch Karrer for numerous suggestions.

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Physical Laboratory
The United Gas Improvement Company,
Philadelphia, Pa., July, 1915.

Water Power in Washington Enormous. ANON. (*U. S. Geological Survey,* Water-supply Paper No. 369.) Not every one realizes that Washington is one of the three States credited with having the most water power, or that the streams of the Pacific coast states furnish about 40 per cent. of the total estimated available water power of the United States. Eventually hydro-electric power must be a dominant factor in the development of large manufacturing enterprises in these states.

The United States Geological Survey and the Washington Board of Geological Survey, of which Governor Ernest Lister is president and Prof. Henry Dandes is geologist, are coöperating in investigating the water supply of the state and the related physical features that affect the development of power and irrigation.

Yakima River is probably the most valuable stream in the state. It can supply water for irrigating about 650,000 acres of land, besides furnishing 132,000 horse-power continuously and an additional 155,000 horse-power for pumping water during the irrigation season. The fact that only 300,000 acres of land are now irrigated, and that only 14,000 horse-power is available from present power plants, indicates great opportunities for agricultural and industrial expansion. All the power estimates in the report have been based, therefore, on the assumption that the water is more useful for irrigation than for power.

The estimates given indicate that Naches River, which joins the Yakima just above North Yakima, can furnish more power than the main Yakima and Clealum Rivers combined when the water supply is regulated for irrigation. A summary of power available on Naches River and its tributaries shows that 97,900 horse-power can be used continuously, and that an additional 62,000 horse-power can be used during the irrigation season for pumping water to lands which can not be served by gravity systems. Most of the power sites on Naches River will require relatively short transmission lines for the delivery of energy.

The essential feature of the scheme of development followed by the United States Reclamation Service is that providing for the use of stored water to supplement the supply when the streams are at low stages, a feature involving the construction of five large reservoirs having an aggregate capacity of 1,069,000 acre-feet of water. Two of these reservoirs have been completed and work on a third is well advanced. These reservoirs will be used exclusively for irrigation, but a number of smaller reservoirs can be used for power and will provide also for an increase in the water available for irrigation.

A copy of Water-supply Paper 369 may be obtained free of of charge by applying to the Director, U. S. Geological Survey, Washington, D. C.

PRODUCTION OF LIGHT BY ANIMALS.*

BY

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LUMINOSITY IN THE ECHINODERMS.

This large group of animals seems to be very near to lacking any luminous members. The class crinoidea show no such examples, although they nearly all live in the deep sea, where the luminous animal appears especially apt to develop, or, to put it more correctly, where animals appear more apt to develop the power of producing light. Also they would quite surely be found in such a position if they had this power, because the deep-water dredging is done from large boats, and the hauls of the dredge, taking hours to come to the surface, often arrive on board the vessel in the night time, when the expectant scientists would see any light and be able to pick out any luminous form and report it.

Among the class asteroidea we have one genus, several members of which have been reported as showing light, the genus *Brisinga*. Mangold denies this, however, and the subject seems to need accurate observations which should be made. It appears that the deceptive appearance of light is due to refraction phenomena caused by the structure of the animal's integument. Still more doubtful is a report that a member of the class holothuroidea is luminous. This very old report (by Ehrenberg) is so obscure that it is not certain whether he refers to the echinoderm of that name or whether he is using the very old name for *Physalia*.

Again we come to a doubtful case in the class echinoidea. These are the well-known "sea-urchins," and among them is a common tropical species, *Centrechinus setosum*, formerly *Diadema setosum*. Many observers have noted on this animal, whose various species are usually of a deep blue-black color, a series of bright blue, iridescent points or dots extending in lines over the upper surface of the body. The largest of these spots are found.

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* Continued from page 261, February issue.

one each, on the genital plates. Also rows of them extend down on the interambulacral plates between the bases of the long spines. They number from one to two thousand altogether, and are slightly raised from the surface, this condition being due to the thickening of the epidermis at this point.

In section under the microscope these spots show a series of hexagonal prisms of transparent refractive material extending from the surface down to the base, where they are fitted into cup-shaped cells whose cytoplasm is filled with a black pigment. The whole structure lies directly upon the general nerve-tissue layer that covers the whole body under the epithelium. A large number of nerve ganglion-cells are found in this nerve-tissue layer at the point upon which the organ lies.

Two functions have been attributed to these organs. The Sarasin brothers and others have said that they were compound eyes, while Ludwig and Haman have taken them to be luminous organs. It must be remembered that both eyes (light-receiving organs) and photophores (light-giving organs) often have the same accessory structures as lens, iris, reflectors, or protectors of some kind. They are, therefore, often confused with eyes in the more specialized forms, especially when examined in the dead specimens, and we will meet with other doubtful forms in our future studies of the higher animals, such as fishes, crustaceans, worms and mollusks. Many cases have been formerly identified incorrectly as one or the other kind of organ and are now known correctly after careful study. In this case we have observations that point both ways, and very careful study is necessary in the future to decide which these organs on this sea-urchin really are. The case seems to be almost decided by observations and experiments made by Dr. L. R. Cary, Dr. A. G. Mayer, and the writer as follows: Fresh living *Centrechinus* were examined in their habitat on the coral reef at the Tortugas laboratory of the Carnegie Institution and in full sunlight. These animals have very long, sharp spines which pierce the flesh of any enemy that happens to touch them, however, lightly. When a hand was passed over them so as to intercept the bright daylight, all the spines on the creature's body were moved so as to point directly at this hand. If the hand was moved, the spines followed it slowly. Thus it was shown that the organism could see in all directions and could distinguish the direction of light—

a work that requires a fairly well organized eye. Since the light-blue spots were the only eye-like organs present, it seems that sight must be their function.

Dr. L. R. Cary, at the writer's request, took these sea-urchins and attempted to stimulate them to luminosity in the dark by both mechanical and chemical means. He failed to get any luminous response. On the other hand, we have the observations of Dörderlein, who, upon taking the animals from the water, saw a beautiful light at the approximate points where the blue spots are found. It is possible that he observed the creature in a half light whose rays were collected and focussed by reflection from the optical apparatus of the blue eyes; or the organism may have both eyes and light-producing spots. The writer and Dr. Cary have both seen this reflection effect in bright daylight, but not in dim lights. In conclusion it may be said that this sea-urchin most probably has eyes, but no light-producing organs.

In contrast to the four classes mentioned above we find in the fifth class of echinoderms, the ophiuroidea, that nearly all of its members, called the "brittle-stars" or "snake-stars," have well-defined light-producing organs (see Fig. 1). This power has long been recognized in them, as many of their specific names will show, such names as *Phosphorea*, *Noctiluca*, etc., being common.

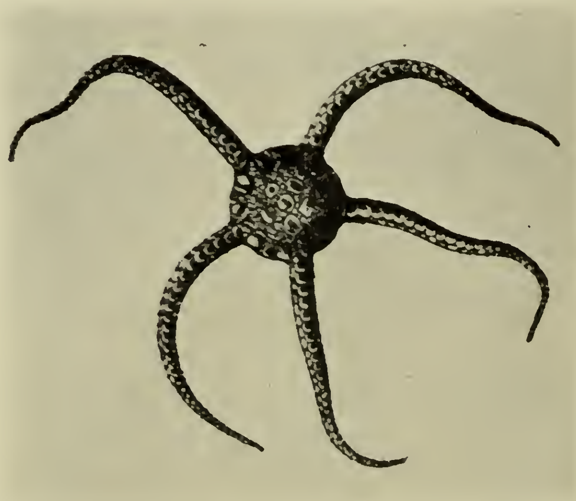
These animals live on the bottom of the sea, in water of various depths, according to the species. They are capable of rapid crawling or creeping motions, and live on gravel or among the stems of sea-weeds or under loose rocks, etc. Their crawling motion is performed by means of the five arms, one of which is held out straight before or behind, while the other four become arranged as two symmetrical pairs that are alternately advanced and pushed backward, thus moving the disk-shaped body forward.

The fact that these animals could light has not been announced as long ago as in the case of some of the other organisms treated of in this work. Nor were the early announcements more than mere mentions of the fact that the *Ophiurians* could shine. The names of some of these more or less superficial observers were Sokolow, Awerinzew, MacIntosh, Godlewski, Viviani, and Tilesius. As an intermediate group of somewhat more careful observers came Wyville Thompson, Panceri, Quatre-

fages, and Molisch. Lastly, in recent years, we have four investigators, Mangold, Reichensperger, Trojan, and Sterzinger, who made careful studies of these interesting animals with reference to the light that they are able to produce and have given us a fairly complete knowledge of the structures that represent the light organs.

Not all of the species are luminous, but the majority appear to be so. The light is fairly strong, and the various reports show that it is bright green in color. The animals show it only upon

FIG. 1.



Photograph of a brittle-star or Ophiurian, *Ophioglypha bullata*. (After Hertwig.

the usual stimulations by chemical, mechanical, and electrical methods. Fig. 2 shows some brittle-stars as they appear when illuminating in an aquarium or in the sea. Before describing the parts of the animal from which the light emanates it may be well to briefly describe the plan upon which the creatures are formed (see Fig. 1).

The hollow body containing the digestive, reproductive, and excretory organs is a round disk, and from this central part five long, slender arms branch out. These arms are solid and composed of a series of segments that grow smaller in size towards

the tips. Each segment is formed of a number of plates that may be described very roughly as a dorsal, a ventral, and two lateral plates (see Fig. 3). Two long, fleshy feet and two smaller feet come out of openings in the outer edge of the ventral plate, a number of spines (ten in *Ophiopsila annulosa*) protrude from each lateral plate, while the dorsal plate is bare of appendages. Fig. 4, 1, is a diagram showing the relations of spines and feet to the plates in a segment as seen in a sectional view of the arm.

Wyville Thompson described the light as appearing on the

FIG. 2.

Picture drawn to show the appearance of brittle-stars shining on the bottom of the sea. (Original drawing by E. Grace White from descriptions by Sterzinger, Mangold, Trojan, Molisch, and the author.)

dorsal part of the disk and arms in *Ophiacanthia spinulosa*, but in the various other forms studied by the four recent investigators mentioned above it appears to be confined to parts of the arms alone, it being difficult to define these spots exactly. Sterzinger states that it comes from the ends of the longer feet, while the others find that it probably comes only from the little plates from which the spines are given off and from the lower parts of the spines themselves.

Mangold shows this in one fairly conclusive manner (see Fig.

5) by first examining portions of the arms in a good light to get the form of the structure and then making another examination in the dark and sketching in black the shape of the lighted regions. He also worked in the same way to determine the location of the light in several other *Ophiurians* found in the waters of the Bay of Naples. The following list will show the result of his work, as well as the apparently trustworthy external observations of some other writers:

Ophiacantha bidentata.—Light appears on the spines, on the basal plates of the spines, and on the lateral plates (Sokolow).

FIG. 3.

Dorsal or top view of part of the arm of a brittle-star, *Amphiura squamata*, to show the spines, plates, and feet. *sta*, spines; *f*, foot. (After Sterzinger.)

Ophiacantha spinulosa.—Light appeared on specimen brought up fresh in the dredge. It was seen on the edge of the body disk and moving inward to the middle, also it appeared at the tips of the five arms and moved inward toward the body (Wyville Thompson). This latter account should be re-investigated.

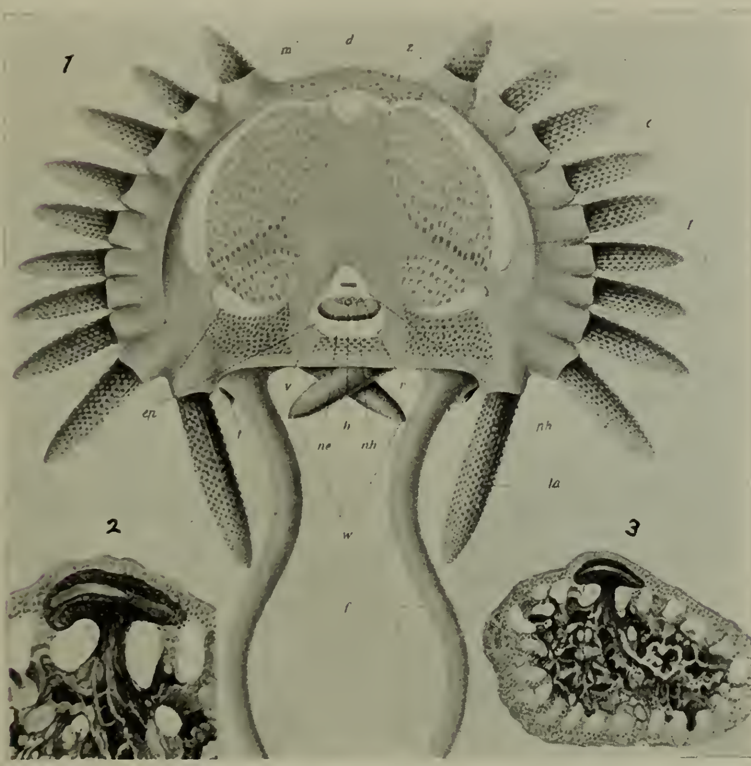
Amphiura squamata.—The light appears only on the proximal portions of the two basal plates of the spines on each segment.

Ophiacantha spinulosa.—The light appears to come from the ambulacral feet, according to Trojan.

Amphiura filiformis.—Only the spines light in this species, as described by Mangold.

Ophiopsila annulosa.—Here Mangold states that the light is

FIG. 4.



1. Semidiagrammatic view of a transverse section of an arm of the brittle-star *Ophiopsila annulosa* to show the relations of the plates, spines and feet. *d*, dorsal plate; *v*, ventral plates; *l*, lateral plate; *la*, spines; 2 and 3 represent stained microscopic sections of spines at points that show the mushroom-shaped reservoirs in which the luciferine from a number of light cells is stored. (After Trojan.)

produced from the entire ventral plate, the lateral plates, and all the spines. Also it appears to come from the ciliated feet.

Ophiopsila aranea.—A much more limited area was illuminated in this form than in the last. Only the proximal part of

each lateral plate bearing the spines was involved, the distal portion remaining dark (Mangold).

Amphiuria chiajei.—No light shown according to Mangold.

Histological studies have been made by several investigators

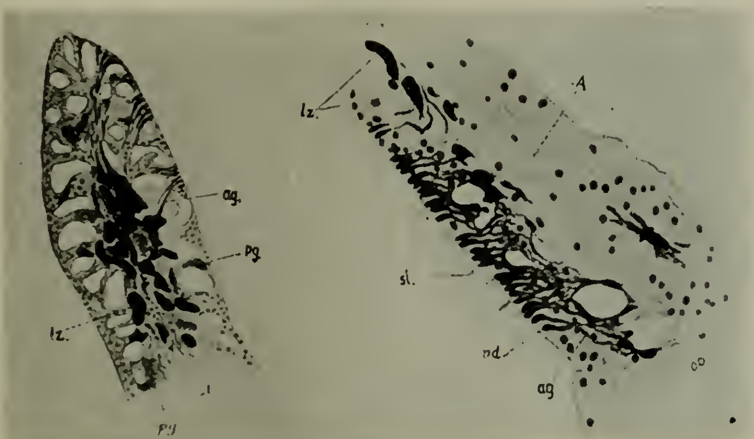
FIG. 5.

Diagrams of several segments from different parts of the arm of the brittle-star *Ophiopsila annulosa* to show the regions that are luminous during light production. On the left are seen the segments as seen in daylight. On the right is marked in black the shape and extent of the luminous areas of these same segments when the animal is excited to luminosity in the dark room. (After Mangold.)

to determine the cells or tissues that were the seat of the secretion of the luciferine and also to find out if it was an internal or intracellular light production, or if the luminous material was forced out of such cells and oxidized in the sea-water.

Reichensperger and Trojan examined sections of all of the above listed forms and from among several kinds of cells picked out one particular variety that seemed to be the specific cell for light production. This cell (see Figs. 6 and 7) is large, it lies deep in the tissues of the spine or plate, its cytoplasm is filled with granules that appear to stain in a measure like those of other light cells, and both observers agree that the heavy cell body stretches out into a prolongation that reaches to the surface of the body. They disagree, however, as to whether it opens through the very thin cuticle at this point. Such openings seem to be present, although

FIG. 6.



Section through a spine of *Ophiopsila annulosa* (left) and through part of a lateral spine of *Amphiura filiformis* (right) to show the light cells as stained with a dark stain. *lz*, light cells; *ag*, ducts; *pd*. enlarged reservoirs on distal portion of duct. (After Reichensperger.)

very small, but their presence does not altogether settle the question as to the exact site of the light production. The observations and experiments of most of the observers point to the fact that no secretion is discharged that can be rubbed off on the fingers and continue to light for even a fraction of a second. Therefore, Trojan concludes that the light must come from inside these cells. Mangold points out that if this is true the light must come only from the distal part of the cell, at a point just under the cuticle where the prolongation of the cell, which has been called its duct, is perceptibly enlarged to form a sort of reservoir. In

this way the light would appear to come from the exact areas as determined by Mangold, because the secreting bodies of the cells themselves are scattered quite widely, while their long ducts are collected so as to open well within the designated areas. Or it may prove that the luciferine is discharged, but is consumed so instantly that one sees no trace of it outside of the body.

Trojan describes a modification of the small storage spaces found on each light cell, as a mushroom-shaped cavity under the surface of the spine (see 2 and 3, Fig. 4). Into this several light cells seem to empty, although Trojan declares he has not seen this, and if this is the seat of light production, the light ought to appear as a series of larger spots on the surface of the light areas.

The idea expressed by some that the secretion from the light cells is drawn from the cells and distributed through the tissues, particularly through the muscle tissue, where it produces the luminosity, is evidently incorrect. The internal structure of the light cells seems not to have been well worked out. Trojan speaks of a nucleus, but he has left the reader in doubt as to the structure of this nucleus, from both text and figures, in which no nucleus is designated or distinguished in any way from the vacuoles that are pictured. Reichensperger, on the other hand, has designated these spaces, one in each cell, as the nucleus, and shows a weak nuclear membrane and some chromatin structures. It is probable that the processes of decalcification have injured the staining power of the nuclei or even their structural features.

LIGHT PRODUCTION AMONG THE LOWER MOLLUSKS.

Referring to the lower mollusks as all classes exclusive of the cephalopoda, or squids and octopus, we find that in these four classes, the Amphineura (the sea limpets), Gasteropoda (slugs or snails), Scaphopoda (sea teeth or tooth snails), and the Pelecypoda (bivalved mollusks), there are remarkably few luminous forms. In fact, only two genera are decidedly well known as being able to light brightly, the gasteropod, *Phyllirrhœ bucephala*, and the pelecypod, *Pholas dactylus*. Remarks on the reported autogenous light from some of the other forms will be made at the end of this chapter.

Phyllirrhœ bucephala is an opisthobranch gasteropod of small size that has assumed a distinctly pelagic form of life, living

on the surface of the warm seas of the tropics and having adapted itself to this life by the development of transparent, watery tissues and a habit of swimming. When first seen in a glass dish among the numerous other animals taken in the surface tow net on the open parts of the Mediterranean Sea and South Atlantic Ocean one cannot for a moment realize that it is a gasteropod mollusk, although a closer inspection soon proves it to be so.

Owing to its aberrant form and habit, which, as has been said, distinguish it from the great majority of other gasteropod

FIG. 7.

Sections through a lateral spine (left) and a foot papilla (right) of *Ophiopsila annulosa* to show the light cells (left) and their ducts and reservoirs and openings (right). Letters same as in Fig. 5. (After Reichensperger.)

mollusks, *Phyllirrhœ* has been much studied as to its morphological organization and histology. In fact, the work of Eschseholtz (1825, 1834), Quoy E. Gemaird (1851, 1853), Cantraine (1841), Souleyet (1846), Leuckart (1851, 1863), Krohn (1853), Muller (1853), MacDonald (1855), Schneider (1858), Costa (1863), and many others, on its structure and comparative morphology have made it a zoological classic, as its figure on the pages of many text-books of zoology will testify. Owing to the fact that these workers always saw and studied the living animal

in daylight, however, no one of them seems to have been aware of its light-producing power.

When the creature is left at rest in an aquarium of fresh sea-water of the proper temperature to rest until nightfall, and is disturbed in the dark with a stroke from a glass rod, it gives off a brilliant light in which its entire shape as well as the outlines of its digestive tract and reproductive glands, etc., are plainly visible (see Fig. 8).

FIG. 8.

Illustration depicting the appearance of *Phyllirrhœ bucephala* as it appears in the sea when lighted. Two individuals out of the six are shown in the state of maximum illumination. (Drawing by E. Grace White after description by Panceri, Trojan, and the author.)

Four men have studied this mollusk with special reference to its light-producing power: Panceri in 1873, Putter in 1905, Vessichelli in 1906, and, most carefully of all, Trojan in 1910, in an article dealing with both the physiology and the structure of the light organs.

Panceri's work was of high scientific value, considering the period in which he worked. Nevertheless he fell into many errors that have been corrected by Trojan, who also made further ad-

vances in the subject. The method of stimulation shows many interesting features.

Like many other of the forms we have noticed, the creature swims about and shows no trace of light if not disturbed. Upon the least disturbance, however, such as the gentle shaking of the dish or a touch with a needle or a glass rod, the organism lights up suddenly, all parts of the outer surface at once. The light then fades gradually until it disappears in about ten seconds. One must have care in using the mechanical stimulation on account of the extreme delicacy of the transparent tissues of the animal. Fig. 8 shows this condition of lighting well.

Both chemical and electrical stimuli were used by Panceri and Trojan to study the lighting. Fresh water, and especially distilled water, furnishes one of the best means of getting a strong light that lasts for fully two minutes. Dilute acids and dilute ammonia both gave excellent results, although all the chemical forms of stimulus kill the creatures at the end of the lighting period. Weak organic acids or mineral acids will cause light to be shown for as much as three minutes. Ammonia causes a bright flash, but also a very short one. All these chemical stimulations not only kill the animal, but also render its tissues unfit for further histological work.

Panceri used the electric current as a stimulus with no success. He probably did not have the proper apparatus for applying it. Trojan found it to be the best means of studying the light, because it could be used a number of times without injuring the organism in the least. His method was to take the *Phyllirrhæ* out of the water, on account of the chemical changes in the water, and to apply non-polarizable electrodes, leading the current from Bunsen plate batteries with an inductor. By applying the current slowly or quickly he could get a weak or a sharp light, and, after allowing the animal to rest, could repeat the experiment.

When stimulated in this way the creature lighted strongest on and about the head and anterior part of the body; less so on the posterior part of the body and on the feelers. The light was well marked on the upper and lower edges of the body so as to outline it plainly. Also several very large points of light were visible on the middle of the sides, both before and behind. Fig. 8 shows these points clearly. With the naked eye the effect was that of a general illumination, except that the large points on the middle

stood out. With a magnifying glass, however, or with a low power of the microscope, it can be seen that all of the light comes from very many, mostly small, points. Further, these points are not all constant in their brilliancy, but the light comes and goes—glimmers, as it were—giving the effect, on the whole, of a constant glow when not too closely examined.

Trojan, in looking for the histological structures that produced the light, noted that the lights were small and thickest set on the contours of the body; that there were not so many on the feelers, and that the few very large ones were in the middle position on the sides. He therefore cut transverse sections and examined the outer integument of these to find some structures that would correspond to the size and position of the points of light. Such organs would undoubtedly be the points of origin of the luminosity.

The body was bounded by a simple epithelium and, at intervals, certain cells had become glandular in nature and had been depressed from the epithelium and their proximal ends sunken deep in the connective tissue of the animal's body. This condition was necessitated by the greatly enlarged size of the cells, whose distal cytoplasm had become filled with secretion. Fig. 10 shows the different kinds of cells so found.

Two principal kinds of these cells are described by Trojan. The first is somewhat the larger, averaging 30 microns long and 18 microns wide (Fig. 9, *Lc*). The cell wall is not distinct from the included mass of secretion in most preparations. This cell wall includes the cytoplasm of the unit, and the nucleus lies at or near the proximal end of the cell in this thickened cell wall and cytoplasm. Lines of a denser nature spread in an irregular radiating way from the area in which the nucleus is placed, and, becoming smaller, fade away about half way toward the distal end of the cell. The nucleus, cytoplasm, and cell wall, as well as the radiating lines in the cytoplasm, all tend to stain deeply with iron hæmatoxylin, especially the nucleus and the lines.

The contents of this cell form a mass or plug of finely granular material whose outer surface is much mixed up with the inner reticular surface of the cell body (walls). This mass protrudes from the distal end of the cell, where its throat-like distal end opens through the surface as a small pore. In many cases that mass has been partly or almost entirely discharged and only a

remnant is left in a proximal position. The granular material stains deeply with such stains as iron hæmatoxylin, thionin, mucicarmine, and mucihæmatin. In this staining power, in its granular state and in other ways, it agrees with the secretions of lighting cells in some other forms, and it seems probable that these cells are the lighting cells of *Phyllirrhæ*.

Two other factors, make this seem even more probable. The

FIG. 9.

Microscopic sections taken vertically to the surface of the body of *Phyllirrhæ bucephala* to show the tissue structure in the light-producing regions. *Ac*, albumen cells; *Lc*, light cells; *Lg*, light glands composed of two or more light cells; *N*, nerve; *Ne*, nerve-ending; *Nu*, nuclei. Modified after Trojan.)

cells in question seem to correspond in number and in position to the light spots as observed on the living animal, and the innervation of these cells as described below seems to make the fact quite certain.

Transverse sections of the body show the larger number of these light cells on the upper and lower border of the body where the light is brightest. Also the cells are small here and close-

set, which corresponds to the appearance of these light spots in the same place. Then, again, the localities occupied by the few very large light spots were examined by Trojan, and here he found the interesting fact that several light cells had united as a gland to form a single point of light production (see Fig. 9, *Lg*). From two to as many as twenty cells are sometimes thus united. Their ducts do not form a common opening of any extent, but they do pour out the secretion at what is practically a single point. In this interesting animal we can see the process of specialization going on and many-celled glands or specialized light organs being formed from a scattered group of light cells distributed all over the body.

A most interesting point in connection with its light cell is that each cell has a nerve-fibre coming to it and attached to it by means of a nerve-end organ (Fig. 9, *Ne, N*). This fibre comes from some internal ganglion, and in most cases can be traced some distance back from the light cell to a branching point where another branch or other branches run to other light cells. Connective-tissue cells are very sparingly found on the nerve-trunks and fibres, and nerve-cells have been described near the branching points, but the origin and structure of the nerves has not been carefully worked out. The nerve-ending is large and consists of a conical swelling on the side of the light cell, with the nerve entering at the apex (Fig. 9, *Ne*). This swelling is marked off from the general cytoplasm of the cell by a plane from which a number of short, equally-placed rodlets radiate into the cell cytoplasm and fade in its substance. These rodlets begin in this plane sharply and are equally spaced. They stain with iron hæmatoxylin. A small, dark body appears in the central part of this pyramidal mass of the nerve-ending. Trojan calls it a small nucleus, but it should be further studied and may not be one.

We can now understand to some degree how this cell may operate. It undoubtedly starts the release of light energy in response to a nerve impulse. This is very apparent when we remember that the whole number, several hundreds or thousands, of the light cells suddenly blaze out at once, no matter how or where the animal's body may be stimulated. This points to a central ganglionic control, and careful experiments should be undertaken to assure ourselves that this assumption is correct.

Such experiments should include a more careful set of local and general stimulation experiments, as well as the cutting of designated nerve-trunks and the artificial control of the several ganglia or their local destruction. The animal, although small, is very transparent and should lend itself readily to such tests.

When the nerve impulse has once arrived at the cell, however, other interesting questions arise. Is any specific chemical or vital action set up that causes the appearance of the light? Or is the result of the nerve discharge merely a muscular and mechanical one which causes the approximation of the luciferine or oxygen, and of the necessary enzyme, oxidase, or organic catalytic agent, all of which are necessary for the appearance of the light?

A closer examination of the structure of the cell will help us to get some working hypothesis. In structure it is undoubtedly a gland-cell with its nucleus pressed down against the proximal surface and a large mass of secreted material filling its internal cavity and being pressed up out of a distal pore so as to be forced out into the surrounding water. This condition can be seen in two of the light cells in Fig. 9. Further, the presence of the dark-staining strands radiating from the nuclear position, and the rods that radiate from the nerve-ending, may indicate the presence of muscular element in the cell which could be used through the stimulus of the nerve discharge to press out the secretion. This assumption is not even necessary, however, as we know many unicellular glands throw out their contents upon nerve stimulation without the presence of any such fibrils. The perinuclear fibrils may, and probably are, secretion fibrils, and the rods around the nerve-ending may be associated with the reception and distribution of the nervous discharge.

No one has established the fact that a luminous secretion has been thrown off as in *Pelagia* or *Chætopterus*, but it may well be that the luminous action can take place at the instant of discharge and the material, when once separated from the body surface, can already be exhausted. Or the light-producing action can even take place in the distal part of the cell before the substances have emerged from the cell pore.

The presence of other and different cells, often associated with the light cells, must be considered. From their affinity for dyes such as eosin, Trojan took them to be albumin cells. They

appear in Fig. 9, *a.c.*, and show a different structure from the light cells. They, too, are gland-cells, but in some cases the efferent duct or pore was not seen. In others this duct was visible. The possibility remains that these structures secrete the necessary enzyme, and their frequent proximity to the light cells points to some such use. On the other hand, they are hardly numerous enough, and many light cells are without them. They may be poison cells, and that appears the more probable when we remember that the animal is undoubtedly poisonous to other creatures and that these albumin cells seem the only or, rather, the easiest way of explaining that.

The color of the light has not been studied at all. Mention has been made of it as "white" and "bluish."

Several other pteropod, pulmonate, and heteropod mollusks, as has already been mentioned, have been reported to light, but no scientific study of them has been made. We can with some confidence believe that a small proportion of these reports have a foundation in fact. Against it is the truth that the mollusks in general, the cephalopoda excepted, show but little inclination to produce light. In favor of it, we must consider that the pteropoda and the heteropoda are surface-swimming pelagic forms, and that all such groups are peculiarly apt to develop the light-producing power. I should expect the pteropoda especially to have some species that have developed a luminosity.

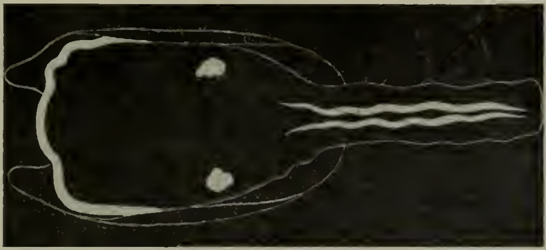
Turning now to the pelecypoda or bivalve mollusks, we find that great exception that proves the rule in a mollusk which we would least expect to possess a luminous organ. This clam-like species *Pholas dactylus* is a form that buries deep in hard mud and soft stone or rotted wood and lives deep below the surface. It is possessed of a long, extensible siphon which it protrudes up through the ground until its tip opens at the surface and is used to provide the creature with an incurrent and an excurrent stream of water bearing the life-giving oxygen and the food supply of diatoms and other small plants and animals.

When this mollusk is opened, it is found that it possesses three pairs of well-developed, simple, and very powerful light organs (see Fig. 10). Each organ consists of a modified region of the integument, and they are distributed as follows: One pair exists as two long, somewhat narrow strips placed symmetrically and laterally on the siphonal septum in the excurrent canal. They

occupy two-thirds or more of its length, and are placed nearer the base than the tip of the siphon. Another pair are two triangular regions on the outer sides of the two retractor muscles, where they become part of the body mass. The third are long, narrow organs found on the inner edge of the mantle and touching each other by their median ends so that they form a single line, bent into a roughly horse-shoe-shaped form that partly surrounds the foot opening. Fig. 10 shows the general position of these organs as seen in the dark after the animal has been cut open and its shell spread somewhat apart.

In structure all these organs are almost alike. The integument is thickened at this point, and the simple epithelium that

FIG. 10.



Panceri's figure illustrating the region of luminous tissue in *Pholas dactylus*. The animal is supposed to be cut open from the ventral side. (After Panceri.)

covers all parts of the body is modified at this point so that it consists of three layers (see Figs. 11 and 12). The first and outer layer is made up of the original long, simple epithelial cells of this region slightly modified. They are somewhat longer than usual, and the cilia that they bear have become over twice as long as in other similar places. These cilia each emerge from the cell from a tiny granule in its distal surface and pass through a thin, delicate cuticle to the outside. Inside the cell they have parallel, rod-like, protoplasmic continuations such as have so often been described in ciliated cells. These structures are parallel except where they make room for the nucleus.

The next layer of the organ lies just below this and is made up of a mass of unicellular glands more or less massed together and with their distal ends prolonged into long, thin ducts that push between the epithelial cells and open to the exterior (see Fig. 12). A good-sized nucleus is found in the proximal base of this

cell, and its body is mostly taken up by the secretion, which is a vacuolated mass that takes iron hæmatoxylin, hæmalum, mucicarmine, and other similar stains deeply. Förster takes the view that these cells produce nothing but mucin. The writer is not yet willing to admit that such is the case, for reasons which will be given later on.

The third and deepest layer is also a set of unicellular gland-cells derived in the same way as the last, from the surface epithelium, but farther removed from the surface by a greater elongation of the duct (see Fig. 12). These ducts, of course, pass between the mucin cells to effect an outlet through pores between the epithelial cells just as the ducts of the mucin cells do. The

Fig. 11.

Section of one of the luminous organs in *Pholas dactylus*. *Lc*, region of luminous cells; *mc*, region of mucin cells. (Outline drawing by E. Grace White.)

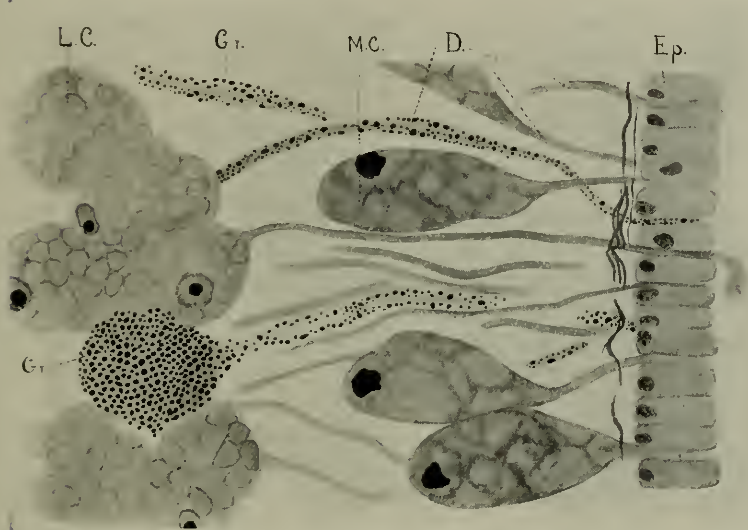
cell bodies are, under normal conditions and when not too much crowded, elongate oval in shape. In many cases, where numerous and especially where filled with much secretion, they become many sided and, on account of their thin walls, hard to distinguish from one another. They average roughly about 40 microns long in the body and 30 microns wide, while the ducts measure from 50 microns to 450 microns, according to the size of the organ and in which level of the general light cell layer their cell parts are situated. They do not always form a single layer, but from the exceptional single row of cells up to as many as seven irregular rows deep in the larger organs. Each cell shows a single nucleus of irregular outline and containing a single body, a combination of plasmosome and chromatin, round

and homogeneous. The nuclear membrane is well defined and the nucleus measures about 4.7 microns, while the spherical chromatin-plasmosome is very uniformly 2.1 microns in diameter.

The cytoplasm of the cell is of uniform structure throughout and shows a series of areas of a homogeneous, apparently fluid material. This substance is inclosed in the meshes of an alveolum of a firmer and darker-staining material whose spaces are polyhedral in form, much as a mass of soap-bubbles would be.

Förster describes some interesting changes in the contents of

FIG. 12.



Enlarged portion of a microscopic section of one of the luminous organs of *Pholas*. *mc*, mucin cells; *lc*, light cells; *d*, ducts of light cells; *gr*, granule mass in ducts and cells. Cilia and cuticle not shown in this preparation. (Original drawing by E. Grace White.)

this cell just before it becomes ripe for discharge. According to his account, the contents of the alveoli change from a homogeneous, fluid, non-chromatic condition into a series of small and very uniform granules which measure about 3 microns by 2.1 microns. These granules have a definite structure with an internal core and an external cortex in which certain dark-staining bodies are present.

When fully ripe, Förster shows these granules as entirely filling the cell and in contact with the nucleus. This is an unusual

condition in a gland-cell of this type, and the more so that each cell should show a complete state of ripeness such as is usually found only in cells that do not regenerate but die with the discharge of their ripened contents. That these oval granules are the real luciferine would appear to be the case, since they are visible as points of light in the discharged secretion.

Another possibility is that the luciferase is also secreted in the lower layer (light cells of Förster) and is discharged through the same ducts as the luciferine, the light being inhibited up to the time of discharge by the absence of oxygen. In regard to such a possibility the writer has often seen a homogeneous non-staining material coming up and pouring out of the light cell ducts. The finished granules of the secretion show the same staining reactions that the undoubted light granules of the fire-fly and other forms do.

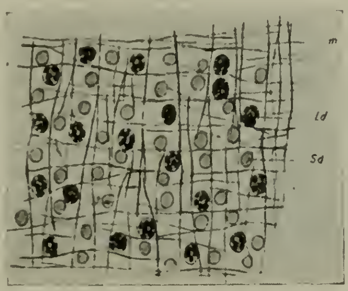
It is probably due to the comparatively large size and definite shape and hardness of these luciferine granules that the light persists so long in water that comes from the mantle cavity of *Pholas*. If a number of these mollusks are cut open and washed about in a pail of salt water the whole body of water becomes brightly luminous and the light persists for some time. If a portion of the secretion is examined with a low power of the microscope or with a strong hand lens that light is seen to emanate from a multitude of points which represent the freed granules of the luciferine.

We must here consider the relation of the mucin cells to the discharged luciferine granules. If the mucin cells secrete only mucin, as suggested by Förster, their use might be easily understood. Thus, both sets of glands would discharge at the same time, and as their ducts open at alternate points, closely intermingled on the surface of the organ (see Fig. 13), we must expect to find the secretions of both mixed with each other. This appears to be true, and in that case the rapidly-expanding mucus would act as a carrier for the heavy luciferine granules and would enable them to be carried out of the excurrent canal with the respiratory stream. But we have not thus accounted for the enzyme luciferase which Dubois discovered in this important form. Since the luciferase is not present in the animal's blood, as in the case of the fire-fly, and since the combustion takes place outside of the body, this enzyme must emerge from the gland in com-

pany with the luciferine and exert itself on this substance in the finished secretion product. The question is, does it discharge from the light cells as a part of the secretion or in company with the granules, or does it come from the so-called mucin cells in company with a true mucus?

The writer studied these mucous cells in careful preparations of his own as well as in Förster's figures, and is of the opinion that the luciferase is a component of the discharge from these cells. For one reason is the fact that numerous other real mucous cells from all over the body of *Pholas* do not stain like these found in the luminous organ. And the contained secretion of these latter cells appears to be a mixture; an alveolum of the blue-staining mucin with contained bodies of some non-staining sub-

FIG. 13.



Horizontal section of light organ of *Pholas* taken at the level just below the epithelium. *m*, muscle fibres; *ld*, light-cell ducts; *sd*, ducts of mucin cells. (After Förster.)

stance that might be the luciferase or the spaces occupied by it in the living state of the tissues.

Both of the above views, one inclusive of the other, are possibilities, and the solution of the question forms a most attractive problem in the field of animal luminosity.

Why should an animal that lies buried in a burrow all of its life need luminous organs, and, further, why should it possess these organs in a cavity in its body? The only way in which the light could be exposed to the eyes of other creatures would be by throwing the luminous slime up through the excurrent canal of the siphon, which several observers have stated to be the way that it does. Further experimental work might be done on this problem of its habits.

The whole three organs show their light simultaneously upon any decided stimulation. This is difficult to observe, because one has to injure the animal seriously in order to expose the six organs to the eye. When opened, however, an hour or less of rest in salt water or in a moist chamber at the natural temperature of the sea from which the organisms were taken will reduce the luminous organs to quiescence, and one can then perform stimulation experiments and study the light.

Förster made a careful study of the nerves that come to the luminous tissues and found all the light organs to be well supplied with large stems that branched out and sent their fine twigs into the tissue of the organ. The exact termination of these nerves, however, was not described: whether each cell of the two layers was provided with a means of being stimulated to discharge its contents, or whether the cells did not connect with the nerve, but the latter ended on muscle-fibres which could contract and squeeze the entire organ so as to press out the secretion. While both of these methods seem possible, the writer thinks that each cell is probably provided with a nerve-ending to enable it to discharge when the general signal is sent out from the central ganglion. If some investigator would open a *Pholas,* cut the nerve-trunks on one side, and then experiment with both mechanical pressures and stimulations of the nerve ganglia, this question ought to be easily solved.

The color of the light in *Pholas* is ordinarily greenish or greenish-blue as seen in the majority of luminous animals.

(*To be continued.*)

Incandescent Electric Headlight Equipment. ANON. (*Railway Age Gazette,* vol. 66, No. 7, February 18, 1916.)—During the past few years the Schroeder Headlight Company, of Evansville, Ind., has given much attention to the development of incandescent electric headlight equipment to meet the growing demand for headlights of this type. At the present time it has on the market three types of equipment, namely, the 6-volt turbo-generator, having a capacity of 150 watts, and two 32-volt generators having capacities of 350 watts and 1000 watts respectively. The 32-volt, 350 watt system has been the most extensively used up to the present time, and has already been made standard on some roads. According to the report of a road operating in the middle West, the average cost of operation is $11.54 per machine per year.

CORRESPONDENCE.

MEMORANDUM ON OPPORTUNITIES FOR THE FRANKLIN INSTITUTE IN CONNECTION WITH AMERICAN LABORATORIES.

DR. R. B. OWENS, Editor,
Franklin Institute.

Dear Dr. Owens:

When The Franklin Institute was founded, in 1824, for the fostering of the mechanic arts, only a very few laboratories existed in America for research in applied science. At the present time there are many such laboratories, and their number is steadily increasing. Almost every technical school in the country maintains a laboratory or laboratories, and in most of these research is carried on, leading to results which find a published record.

The existing American laboratories for work in engineering are of various types, from the national laboratories of the United States Bureau of Standards and other government departments to the little establishments of private amateurs; but, from the standpoint of this memorandum, they may all be divided into two great classes; namely,

First. Those that either publish or attempt to publish their results.

Second. Those that make no attempt to publish their results.

The first class is essentially an asset to the nation and to the world. The second class is essentially an asset to individuals, or to restricted groups of individuals. The suggestions here submitted have reference only to the first class. No consideration is here given to the second or mute class of laboratories, which are mainly elements in purely commercial organizations. These have great and proper value, but are in a class apart.

The idea which it is desired to express in this memorandum is that The Franklin Institute is, by its history, position, and charter, peculiarly capable of fulfilling its functions and aiding the cause of American engineering by paying particular attention to the work of American engineering laboratories in the first class mentioned above. It is here assumed that a broad interpretation

of the term "mechanic arts," as this was used in Franklin's time, would include not only all engineering, but also industrial chemistry, economics, and applied science generally.

If we consider the work of the various American applied-science laboratories to-day, we find that work is going on healthily in each, as a separate point source. Each laboratory, as a rule, works for and in itself, as though it were the only one in the country. It is almost self-evident that the collective output would be improved and the cause of engineering advanced if these various laboratories could be coördinated, without repressing their individual initiative. What is desirable is such a coördination and coöperation between the various laboratories as should intensify their work systematically, without imposing on them either hindering restrictions or burdensome expense.

There are at least four ways in which The Franklin Institute can assist the American engineering laboratories taken collectively:

1. By giving publication, so far as it can, to the results reached in these laboratories. It does this, as I understand it, already.

2. By suggesting subjects for research to such laboratories as seem best suited for them.

3. Inviting subjects from the industries, and grants for the expenses of research.

4. By encouraging mutual understanding between the laboratories.

Theoretically, the American laboratory combination should benefit, both in individual units and collectively, by the growth of specialism, so far as it can be carried without disadvantage. For example, the Bureau of Standards has particular duties in regard to precision of research, and this calls for specialization of that type. It would probably be a great mistake for the average engineering laboratory to attempt a like degree of precision in its measurements. This specialty of the Bureau should be recognized and encouraged. Again, it is a pity to find a number of laboratories all engaging on the same subject of investigation, and none of them engaging on other equally important subjects. The Franklin Institute cannot prevent such bad distribution of labor. It can, however, make such suggestions as will commend themselves by their reasonableness, and, when a particular laboratory develops a specialty on its own account, advantage can be taken

of this to emphasize and recognize that specialty. A very large laboratory can maintain the luxury of a number of simultaneous specialties; but a very small laboratory can only expect to do good work in one at a time.

The national and local benefits which are derivable from a closer coördination and coöperation between American engineering laboratories will tend to assert themselves, if the proper psychological conditions be produced. That is, if The Franklin Institute can succeed in conveying the idea to the workers in the various laboratories that, whether they wish it or no, they form an essential collective entity, on which the progress of the country greatly depends, the laboratories will surely conform more or less to that idea, and work towards that progress, either consciously or unconsciously. If the motion can be fostered that the heartiest and most effective of competition is one which benefits the collective entity, acrimonious competition, where it may exist, would give place to a generous and stimulative emulation. These ideas can be disseminated either by editorial articles in the JOURNAL or by personal communication, or by both means, the object being to favor the collective advantage, and not the advantage of any single laboratory in the collection.

The ideal system, if it could be obtained, would perhaps be one in which the various laboratories were finally united in some very simple, flexible organization for promoting mutual activity. Each would tend to develop a certain specialty or group of specialties, and students seeking information or research along those specialties would select particular laboratories for this purpose. But no rule should be laid down to attempt enforcing any specialty upon any laboratory, or the maintenance of a specialty where that maintenance became a burden. The natural tendency to specialize should merely be recognized and encouraged. The inevitable reward would be the rate of growth in results along the selected lines of work, which would naturally be greater, in the long run, than where the efforts were scattered. The individual laboratories in the organization would naturally ask that questions on their chosen lines should be sent to them. If too many elected one and the same subject, they would soon recognize that the fair division of material among so many prevented each from making rapid progress; and so the tendency of reduplicating unnecessarily should be automatically checked.

It will probably take a long time to bring about an organized system of coöperation between the laboratories; but The Franklin Institute, if it sets itself to the task of fostering the movement impartially, is in a specially advantageous position to bring it about. In just so far as its aims would meet with success should this success benefit and redound to the credit of the Institute, which has nothing to lose if it does not succeed, and much to gain if it does not fail. The money expenses of the undertaking in its initial stages need only be very small. The effort would be principally intellectual and individual. If the movement, however, were to gain headway, the expenses should readily be met. Thus, if the engineering industries desired certain investigations made, they would be likely to apply to the Institute as the clearing-house, and offer, when necessary, a certain sum to defray the expenses. It is assumed that the information desired is outside the province of either consulting engineering, on the one hand, or of the standard testing laboratories, on the other. The Institute would then refer the matter to the laboratory committee, so as to have it assigned to the laboratories best fitted to take up the inquiry. If no laboratory volunteered, no harm would be done. If a laboratory took the matter up, the results, so far as they were attained, would be published in the Journal, at least in abstract, and communicated *in extenso* to the industry. The all-essential requisite to the procedure would be that it should be conducted impartially and for the collective welfare of both the laboratories and of the industry.

In a certain sense, the ideas here suggested have no novelty, because the Institute has for years been doing the sort of thing contemplated. In offering the Boyden Premium, for instance, the Institute has already acted in such a capacity as these ideas would indicate. The novelty, if any then, lies in executing with greater emphasis and earnestness a long-existing policy, looking for evolution and coördination towards effectiveness and public welfare.

Respectfully submitted,

(Signed) A. E. Kennelly,
Life Member.

Massachusetts Institute of Technology,
February 5, 1916.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF INSTRUMENTS FOR MEASURING RADIANT ENERGY IN ABSOLUTE VALUE: AN ABSOLUTE THERMOPILE.[1]

By W. W. Coblentz and W. B. Emerson.

THE PRESENT STATUS OF THE DETERMINATION OF THE CONSTANT OF TOTAL RADIATION OF A BLACK BODY.[2]

By W. W. Coblentz.

[ABSTRACTS.]

The first paper gives the results of an investigation of the behavior of a bismuth-silver thermopile suitably modified to measure radiant energy in absolute value. Instead of exposing the thermopile directly to the incident radiation, a blackened metal strip intervenes. This metal strip functions (1) as a receiver for absorbing radiant energy, (2) as a source of radiations (by heating it electrically) which may be evaluated in absolute measure, and, by using a constant current for heating the strip, (3) as a standard source of radiation for testing the sensitivity of radiometer, which includes both galvonometer and thermopile.

The present investigation relates to 13 receivers, made of manganin, therlo, and platinum, differing in width from 2.5 to 8 mm. and in thickness from less than 0.001 mm. for platinum to 0.011 mm. for manganin. The manganin and therlo receivers were painted with a thick coat of lamp-black, then smoked. The platinum receivers were covered with platinum black and afterwards smoked. In this manner (the same values being obtained in the two cases) it was shown that there is but little difference in the reflecting power of these two kinds of absorbing surfaces.

The method of operation is unsymmetrical in that when the receiver is exposed to radiation the heating is produced in the lamp-black surface, while in passing an electrical current through

* Communicated by the Director.

[1] Scientific Paper No. 261.

[2] Scientific Paper No. 262.

the strip the heat is generated within the receiver. However, from the data obtained with receivers differing 10 times in thickness and covered with different kinds and thicknesses of absorbing material it appears that the manner of heating the receiver has but little effect upon the final result.

For any one receiver, operated under different conditions, the precision attained is usually much better than 1 per cent. For the different receivers the maximum range in the value of the radiation constant, which was caused by two receivers giving high values, is of the order of 3.5 to 4 per cent. Excluding these two receivers, the range of values for the different receivers is of the order of 1.5 to 2 per cent. This seems to be independent of the length and width of the receiver, and of the kind of slits used.

The accuracy attained with this method of evaluating energy in absolute measure, as estimated from the departure of individual determinations from the mean value, appears to be of the order of 1 per cent. To this extent one can consider the present device a primary instrument for evaluating radiant energy in absolute measure.

The device commends itself as an instrument of precision because of its quickness of action, its freedom of surrounding conditions, its high sensitivity, and its simplicity of operation. It can be designed to suit the equipment of the average laboratory. The device can be much simplified and used as a radiation pyrometer, and in practice it is advisable to calibrate the receiver by exposing it to a black body heated to about 1000°, when it is desired to make refined radiation measurements.

The loss of energy by diffuse reflection from the blackened surface of the receiver was investigated, and it was found that there was but little difference in the reflecting power of the different surfaces examined.

The second paper gives a summary of the methods used and the values of the constant of total radiation obtained by various observers. Corrections, for losses by reflection, for atmospheric absorption, and for lack of blackness of the radiator were applied. After making these corrections to the most reliable measurements the large variations in the radiation constant had disappeared, giving a value of the coefficient which is of the order of $\sigma = 5.7 \times 10^{-12}$ watt, per cm.$^{-2}$ per deg^{-4}.

This paper gives also the correction (about 1 per cent.) for lack of "blackness" of the radiations from an unpainted porcelain tube radiator and for the atmospheric absorption in 1.2 m. of air containing a determined amount of water vapor, the radiator being at about 1050° C.

The data obtained in Part I of this paper are corrected for losses by diffuse reflection from the receiver and combined to give a value of the coefficient (the so-called Stefan-Boltzmann constant) of total radiation from a black body. The correction applied to all the data for diffuse reflection is taken as being 1.5 per cent. This correction may be 0.1 to 0.3 per cent. too high for lamp-black, but it will eliminate, in part, atmospheric absorption and the possible lack of blackness of the radiator.

The mean value of the radiation constant (corrected by 1.5 per cent.), as determined by 12 receivers, and representing 348 pairs of measurements, is:

$$\sigma = 5.77 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

If we exclude receivers Nos. 8 and 9, which is permissible in view of the fact that they were known to be defective, the value of the coefficient of total radiation, representing the mean of 304 pairs of determinations, is

$$\sigma = 5.74 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

which is but little smaller than the value obtained for all the receivers. All the determinations are given the same weight in finding the mean value. Each tabulated value represents two sets of measurements, each one of which is a complete determination, consisting of 5 to 10 or more readings when the receiver was heated electrically and when it was heated radiometrically. From the data at hand it appears that the value of the radiation constant is of the order of

$$\sigma = 5.74 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

or

$$\sigma = 1.37 \times 10^{-12} \text{ gr–cal cm.}^{-2} \text{ deg.}^{-4}$$

THE PREPARATION OF PURE IRON AND IRON-CARBON ALLOYS.*

By J. R. Cain, E. Schramm, and H. E. Cleaves.

It is shown that previous work on the iron-carbon diagram is unsatisfactory because of the great uncertainty of chemical composition of the materials used. It was therefore thought necessary to produce a series of alloys of great purity to form the basis of a redetermination of the diagram at the Bureau of Standards. The general method pursued consisted in melting electrolytic iron with sugar carbon in magnesia crucibles. The electrolytic iron was prepared from ingot iron anodes in a chloride bath with or without the use of porous cups. The operation of melting the iron with carbon gave great trouble at first, because the ingots obtained were full of blow-holes and contained considerable quantities of impurities. The difficulties were overcome by melting in a vacuum furnace, and making crucibles of especially pure magnesia, made and calcined with great care at the Bureau of Standards. A satisfactory procedure was finally worked out and a series of alloys prepared of the composition $Fe + C = 99.96$ per cent.

THE COLORIMETRIC DETERMINATION OF ACETYLENE AND ITS APPLICATION TO THE DETERMINATION OF WATER.†

By E. R. Weaver.

A colorimetric method for the detection of small amounts of acetylene has been developed in the course of an investigation upon the determination of small amounts of water by the use of calcium carbide. The results upon the quantitative determination of water have not been satisfactory, but a simple and very sensitive qualitative test for water is easily made.

The method for the determination of acetylene has been worked out successfully. The determination is made by conducting the gas to be investigated into an ammoniacal solution of cuprous chloride containing gelatine and alcohol, and comparing the red colloidal solution so obtained with a suitable

* Scientific Paper No. 266.

† Scientific Paper No. 267.

standard, which may be either a solution of red dye or a piece of ruby glass.

After a careful investigation of the effect of varying the composition of the absorbing solution, the following procedure was adopted in making up the solution: Dissolve 0.25 Gm. of gelatine in hot water, dilute to 500 c.c. and add 500 c.c. of 95 per cent. alcohol, and 1.25 Gm. of hydroxylamine hydrochloride. To 20 c.c. of this solution add 10 c.c. of concentrated ammonium hydroxide and a small amount of cuprous chloride. After the absorption of the acetylene, the solution is diluted to 100 c.c. and compared in a calorimeter with the standard which has been chosen. The standard used in the experimental work was a solution containing chromanilbraun R, carmoisine B, and gum arabic. A more convenient, though less accurate, standard is a fixed depth of a solution of azolitmin. If 10 cm. of a solution of azolitmin containing 1 part of the dye to 2500 parts of water is used as standard, the amount of acetylene in 100 c.c. of colloidal solution may be calculated from the equation $X = 0.13y$, where X = No. of milligrammes of acetylene, and $y = 1/\text{No. cm.}$ of colloidal solution required to match the standard.

The method is very sensitive. Amounts of acetylene as small as 0.03 mg. may be detected, and amounts up to 2 mg. may be determined with an accuracy of better than 0.05 mg.

Hydrogen sulphide and large amounts of oxygen and carbon dioxide interfere with the test, but all of these may be removed by passing the gas to be tested through a hot alkaline solution of pyrogallol without loss of acetylene.

A qualitative test for water, sensitive to less than 0.1 mg., may be very easily and quickly made by bringing the substance to be tested into contact with calcium carbide in the presence of a solvent for acetylene, which is then decanted or distilled into an ammoniacal solution of cuprous chloride. Nearly all the common organic liquids are suitable for use if carefully dried. The method is applicable to a great variety of substances, and especially to volatile organic compounds. The only compounds known to interfere with the test are the stronger acids and substances, such as hydrogen sulphide, which precipitate cuprous salts from solution.

The investigation required some experiments upon the determination of larger amounts of acetylene by precipitation with

cuprous chloride and subsequent determination of the copper. It was found that in order to obtain accurate results by this method it is absolutely necessary to carry out the filtration and washing of the precipitate in the absence of air.

MODERN PRACTICE IN THE CONSTRUCTION AND MAINTENANCE OF RAIL JOINTS AND BONDS IN ELECTRIC RAILWAYS.*

By E. R. Shepard.

In connection with the study of electrolysis and electrolysis mitigation the attention of the Bureau of Standards has been called to the past and present high rate of rail joint and rail bond failures and the consequence of such failures upon the electrolysis conditions throughout the country. With the idea of collecting information on the best present-day practices of bonding tracks a circular letter was prepared and copies were sent to 130 operating companies. The letter asked for information as to the number and types of bonds and joints in use and for the average life and causes of failure of each type; also for the manner and time of testing bonds and the criterion for replacement. Other questions of minor importance were also included.

The present paper is largely a compilation of the data submitted by 42 companies answering the inquiries, and also includes information collected by a representative of the Bureau who spent five weeks in the field and visited upward of fifty companies in the interest of the investigation.

An historical and descriptive discussion of the various types of modern bonds and joints is followed by a compilation and analysis of all available information on each type. Among the principal features brought out in the analysis of the data are the following:

Soldered bonds of all types are falling into disuse. A few companies, however, employing thoroughly experienced and careful workmen still continue to use them.

A large percentage of the many rail bond failures in past years has been the result of imperfect methods of manufacture and of ignorance and carelessness in installation.

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* Technologic Paper No. 62.

Practically all types of modern bonds, when selected to meet local conditions and installed according to the best modern practices, will give satisfactory results with an almost negligible percentage of failures on joints which are properly maintained.

No one type of bond can be said to be better than all other types. Each has its advantages and disadvantages, and the selection of a bond for any particular service should be governed by the type of construction on which it is to be used, the grade of labor available for installation, and upon numerous other local conditions.

The problem of rail bond maintenance is largely that of joint maintenance. No bond can be expected to last continuously on a loose and poorly-supported rail joint.

The surfacing of all newly-installed joints and the tightening of all bolts soon after installation and at regular intervals thereafter will do much to prevent loosening of joints and cupping of rails.

Improved bolts having a high elastic limit and a great ultimate strength appear to be giving excellent results, and their universal adoption is recommended on all new work.

Difficulty has been experienced in obtaining sufficient room for concealed bonds, particularly on the smaller rails. This difficulty has been largely overcome in several of the improved patent joints now on the market. It is recommended that bonds and joint plates be selected only after laying out a section of the joint on the drawing-board and providing a proper clearance for the bonds.

The life of concealed bonds on exposed rails is much shorter than on rails in city streets, owing to the expansion and contraction in the joint on the former type of construction. Such expansion and contraction can be overcome by the use of improved mechanical joints, supplemented by expansion joints at regular intervals. It is believed that such construction would prove itself to be of ultimate economy, and is recommended, at least on an experimental basis.

Both the compressed terminal and the pin terminal types of bonds are giving excellent results where proper attention is given to their installation. The former type requires more care in the expansion of the terminal, while the latter type requires greater accuracy in the drilling of the holes. Each has its

peculiarities and should be selected only after due consideration to local conditions.

A strict adherence to the code of bonding rules given in Richey's Electric Railway Handbook is recommended.

Stranded bonds appear to be giving better satisfaction than ribbon bonds, as the conductors of the latter type are more easily separated and broken. Exposed ribbon bonds should have a clip or band at the centre of the bond to prevent this separation of the conductors.

The use of solder in connection with the application of mechanically-applied bonds will undoubtedly add to their life if the work is carefully performed. Its use, however, does not always appear to be justified, as good results under modern conditions can be obtained without it. Its use should depend entirely upon local conditions.

The use of tinned terminals and plastic alloys in connection with mechanically-applied bonds appears to be a good practice. Their use is recommended where trouble from corrosion of terminals has been experienced.

Mechanically-applied head bonds are comparatively modern and are therefore more or less in the experimental stage. However, their use is increasing, and in most installations they appear to be giving fairly satisfactory results. They are short, cheap, and easily installed. Their contact resistance appears to increase with time, but not ordinarily to the point of failure. When installed in city streets they are subjected to vehicle traffic, and some failures must be expected.

Electrically-welded bonds have a low and permanent contact resistance. Theft of this type is difficult, and, owing to the shortness of the bond and its tenacious contact, has been reduced to a minimum. Failures of the head bond from the breaking of ribbons have been quite prevalent, but are being reduced by a modification in the design of the bond.

Welded joints are being used more than ever before, but there is also a growing tendency to adopt improved mechanical joints and various forms of special joints, several of which are a combination of welded and bolted or welded and riveted joints. These special joints seem to be meeting the demands of service with fewer failures and better results generally than any of the standard types.

Power economy alone will not justify the best modern practice in bonding. Such practice, however, is justified and strongly recommended from the standpoint of good voltage conditions in the return circuit, which not only make for good electrolysis conditions, but also for satisfactory operation. The present practice of basing the criterion for bond replacements upon a joint resistance which is defined in terms of the resistance of a given length of adjacent rail is shown to be somewhat irrational, but owing to its simplicity and ease of application the continuation of the practice is recommended. From six to ten feet of rail as the limiting resistance for rail joints is shown to represent good practice, and it is recommended that these figures be not exceeded under ordinary conditions.

The paper calls attention to the fact that the problem of track bonding is in a state of evolution. New inventions and improvements in methods and practices have been so frequent during recent years that many types of bonds and joints can still be said to be in the experimental stage. Carefully-kept records and a free interchange of experiences on the part of the operating companies will do much toward the establishment of definite and standard practice in this particular field.

The paper contains 34 figures.

THE LEAKAGE OF CURRENT FROM ELECTRIC RAILWAYS.*

In this paper the theory of the leakage of current from electric railway tracks is developed mathematically.

Assuming, first, a single track of uniform construction, and, later, a track whose sections vary in conductivity, leakage resistance, and loading, the effects of rail and leakage resistance and of the length of the line on the distribution and amount of leakage current are calculated for systems with both grounded and ungrounded negative buses.

Curves are plotted showing the effects of the principal variables in the formulas developed. The conclusions with respect to electrolysis to be drawn from the formulas and curves are discussed and tabulated. The paper contains 14 figures.

* Technologic Paper No. 63.

THE DETERMINATION OF OIL AND RESIN IN VARNISH.*

By E. W. Boughton.

Existing methods can be classified as follows: (1) calculation of the oil content from the determined glycerol yield; (2) separation by the use of solvents; and (3) esterification methods, some of which include separation of oil and "gum" by petroleum ether. It is shown that method (1) gives fairly good results except with varnish that contains Chinese wood oil. The following methods under (2) were investigated: precipitation of the "gum" by petroleum ether, extraction of oxidized films with chloroform to separate oil and resin, and a combination of these steps. These methods gave poor results. Petroleum ether only partially precipitated the "gum" and precipitated some oil. Only a part of the resin in films containing resin and oxidized oil was extracted by chloroform. Esterification methods which include the use of petroleum ether gave poor results with spar varnish, due to precipitation of oil. With "short oil" varnish they gave good results for total oil and total resin, but the "gum" was only partially precipitated by petroleum ether, the soluble portion being separated from the oil by esterification. A method is proposed which includes esterification by the Twitchell or Wolff methods, ethyl ether being used as solvent after esterification. Since some resinous matter is weighed as fatty acids, a factor is used to correct the results. The greatest error in the average results by the proposed method was 2.2 per cent., expressed as percentage of the varnish.

DETERMINATION OF CARBON IN STEELS AND IRONS BY DIRECT COMBUSTION IN OXYGEN AT HIGH TEMPERATURES.†

By J. R. Cain and H. E. Cleaves.

[abstract.]

A method has been devised for the determination of carbon in steels and irons by direct combustion in oxygen at 950° to 1100° C., finishing above 1450°, so that the oxides of iron are kept fused for several minutes, in order to give the best possible

* Technologic Paper No. 65.

† Technologic Paper No. 69.

chance for liberating all the carbon. This method was tested by analyzing various types of plain carbon and alloy steel standards of the Bureau and some of the pig-iron standards, and the results obtained for carbon in this way were in the mean about 0.01 per cent. carbon above the certificate averages.

THE TESTING OF HYDROMETERS.*

The circular contains specifications for hydrometers, and information and instructions concerning their test. The new edition is not essentially different from the last, only minor additions and corrections having been made.

An Immense Deposit of Magnesite in Southern Nevada. Anon. (*U. S. Geological Survey Press Bulletin,* No. 259, February, 1916.)—A massive deposit of magnesite of unusual character that has recently been brought to the attention of the United States Geological Survey promises to yield a large and readily available supply of this material. The deposit lies in Clark County, Nev., in the valley of Muddy River, one of the tributaries of Virgin River, a few miles above the town of St. Thomas. The material has been known for some time as kaolin, and successful experiments for utilizing it as a porcelain clay are reported to have been made, though they have not yet resulted in the exploitation of the deposit. The recognized outcrops have been located as mining claims, and some preliminary exploration and development work has been done. A side track on the St. Thomas branch of the San Pedro, Los Angeles and Salt Lake Railroad, about three miles northeast of the northernmost group of claims, offers a readily available railroad connection, and the station has been named Kaolin, from this deposit.

The so-called kaolin is stated by the Geological Survey to be in fact magnesite, a part of a regularly stratified series of sedimentary strata exposed by stream channels that cut across a low ridge at the upper edge of Muddy Valley. The deposit forms a chalky-looking bluff, dazzlingly white in the bright sunlight. The material is porcelain-white, fine grained, and massive, is remarkably free from foreign material, but is not so hard as the more typical magnesite, and crumbles more rapidly on exposure to the weather.

The length at the surface of the magnesite deposit seems to be a mile at least, and the purer part of the deposit consists of beds

* Circular of the Bureau of Standards No. 16. 4th edition, revised

aggregating at least 200 feet in thickness. Within the section of purer material there are a few bands of sandy matter, but these are minor in amount and could undoubtedly be avoided in mining. The new deposits are so large and so readily accessible that they may form a valuable source of magnesite.

The greater part of the California magnesite is used in the manufacture of wood-pulp paper on the Pacific coast. Magnesite is coming into use in the manufacture of cement for floors, for artificial marble and tile, and to a certain extent as a stucco for exterior finish. Carbon dioxide is manufactured from raw magnesite, and the use of finely-ground caustic calcined magnesite in fire-retarding paint is now one of its important applications. The larger buildings of the Panama-Pacific Exposition, as well as other buildings on the exposition grounds, were treated with a fireproofing and damp-proofing magnesia paint.

The Stored Energy of the Submarine. ANON. (*Scientific American*, vol. cxiv, No. 7, February 12, 1916.)—Although the idea of underwater attack dates back to the Revolutionary War, it was not until the storage battery was perfected that the submarine became a practical weapon of war. However formidable in attack it may be, it is a relatively frail craft whose only refuge is the sea, under whose cloak it may lurk in wait for the enemy, and in whose depths it may hide after it has hurled its bolt. It can live only by stealth, and so, in order to steal through the water without awakening a suspicion of its presence, it must be equipped with a propelling power that is noiseless and leaves no visible trace of its operation. The storage battery and the motor it energizes are almost ideally suited to the requirements of the submarine, for they are silent and practically heatless, leaving no trail of bubbles to betray the presence of the submerged vessel.

The battery for our large new submarines consists of two units of 60 cells each, and the space occupied by each unit is about 12 feet long by 12 feet wide by 50 inches high. The two units are usually separated by a bulkhead. A complete battery of two units will weigh between 60 and 70 tons and their capacity will be approximately 3000 ampère-hours.

In the earlier days of the submarine it was not realized that a special form of battery was required for this use. At first the batteries were of the open-type construction; that is, the individual cells had no covers. Now submarine batteries are carefully sealed so that the electrolyte can never spill and so that salt water cannot enter the cell and come into contact with the sulphuric acid of the electrolyte and produce chlorine gas. In the latest type of battery each individual cell is sealed. Unfortunately it is impossible to seal a storage battery absolutely, for both in charging and discharging it generates hydrogen and oxygen. These must be carried off and dissipated in the hold of the vessel.

NOTES FROM NELA RESEARCH LABORATORY.*

THE TRUE TEMPERATURE SCALE FOR TUNGSTEN AND ITS EMISSIVE POWERS AT INCANDESCENT TEMPERATURES.

By A. G. Worthing.

The experimental part of the work here reported consisted in measuring the brightness of an incandescent, hollow, cylindrical, tungsten filament perforated with small holes and mounted in a large lamp bulb. Such determinations were first made for a hole and then for the adjacent surface. The ratio of the latter brightness to the former, when corrected for the difference in temperature between the interior and the surface and for the departure from blackness of the radiation from the interior due to the presence of the small hole and any lack of symmetry in the filament temperature distribution, gives the emissive power for the substance at the surface temperature. Because the radiation from tungsten deviates from Lambert's cosine law, the emissive power has in the present work been so limited as to refer only to that radiation which leaves the surface normally.

Black-body temperatures were obtained by comparing the observed brightness, with the aid of Wien's radiation formula, with that of a black body at the palladium point. The true temperature scale consists of the relation thus found between the black-body temperature of the filament surface and that of the adjacent hole; *i.e.,* the true temperature of the filament.

A linear relation was found between emissive powers and true temperatures for the region 1200° K. to 3200° K. such that the emissive powers for the two limiting temperatures were respectively 0.467 and 0.406. The uncertainty in these values should not be much over 1 per cent. The respective corresponding differences between the red ($\lambda = 0.666\mu$) black-body temperatures and the true temperatures are 33° and 375°.

Measurements were attempted on the tungsten arc much after the manner described by Langmuir. Due to large temperature gradients across the molten tungsten, no satisfactory determina-

* Communicated by the Director.

tions could be made of the emissive power. However, it was noticed, contrary to what was concluded by Langmuir, that the brightnesses of molten and of solid tungsten at the melting-point are nearly identical. Assuming the linear relation between emissive power and temperature for solid tungsten to continue up to the melting-point, it follows that this occurs at 3630° K. This corresponds to a red black-body temperature of 3140° K. and an emissive power of 0.390.

Though the results given above are believed to be dependable within reasonable uncertainties of measurement, further verification with other filaments will be attempted previous to the publication of the completed paper.

"COLOR TEMPERATURE" SCALES FOR TUNGSTEN AND CARBON.

By E. P. Hyde, F. E. Cady, and W. E. Forsythe.

By "color temperature" of a solid body radiating by virtue of its temperature is meant that temperature of a black body at which its radiation matches in color that of the solid body in question, provided the radiation from the latter is such that a color match may be obtained. If this is not possible, then the color temperature is that temperature of the black body at which the radiation from the latter has the same relative intensities of emission in two chosen wave-lengths as that from the solid body. It has been shown in previous papers by one of the authors and others that very approximate color matches may be obtained in the case of such substances as carbon, tantalum, tungsten, osmium, and platinum. Moreover, making a simple and very probable assumption, it was shown to follow that for the metals studied the color temperature gives an upper limit, just as the ordinary so-called black body temperature gives a lower limit to the true temperature of the radiating metal.

In the present investigation the color temperature of tungsten is accurately determined by comparison with an electrically-heated carbon tube furnace, and this color temperature scale is compared with the black-body temperature scale and with the true temperature scale of tungsten, as determined by Worthing. The relation is also established between the color temperature and the specific

output in lumens per watt radiated by the tungsten filament. It is found that the color temperature scale, which accurately and very readily defines the temperature of radiating tungsten, is very much closer to the true temperature scale than the so-called black-body scale which has been used generally in the past. Untreated carbon, as in the untreated carbon filament lamps, has also been studied, though with less precision, as the non-uniformity of filament temperature and the variations in radiating properties of different allotropic forms of carbon did not warrant a more accurate study. Moreover, for carbon, no true temperature values were determined, as a satisfactory scale of true temperatures was not available.

The principal results for tungsten are summarized in Table I, all necessary corrections for bulb absorption, etc., having been made.

The corresponding values for untreated carbon, with the exception of the values of true temperature, are given in Table II.

The following mean relations between the color temperature and the total radiation, measured as watts, with all necessary corrections, were determined:

For tungsten $E = AT_c^{4.93}$

For untreated carbon, $E = BT_c^{4.13}$

in which E is the total radiation and T_c is the color temperature, A and B being constants.

TABLE I.

Specific Output, Color, Black-body, and True Temperatures for a Tungsten Lamp.

Lumens per watt	Color temperature	Black-body temperature ($\lambda = 0.665\mu$)	True temperature
1	1763° K.	1627° K.	1729° K.
2	1917	1753	1875
3	2025	1840	1976
4	2109	1909	2056
5	2179	1967	2125
6	2237	2017	2184
7	2290	2062	2238
8	2338	2102	2286
*8.275	2350	2113	2299
9	2383	2140	2332
10	2425	2174	2373

* This value corresponds to 1.2 watts per mean horizontal candle, assuming a reduction factor of 0.79.

TABLE II.

Specific Output, Color, and Black-body Temperatures for a Carbon Lamp.

Lumens per watt	Color temperature	Black-body temperature ($\lambda = 0.665\mu$)
0.38	1672° K.	1647° K.
.55	1736	1707
.75	1795	1762
.98	1849	1815
1.25	1904	1866
1.56	1954	1913
1.90	2003	1959
2.28	2050	2002
2.42	2065	2017
2.69	2095	2045

THE CANDLE-POWER OF THE BLACK BODY AND THE MECHANICAL EQUIVALENT OF LIGHT.

By E. P. Hyde, F. E. Cady, and W. E. Forsythe.

THE candle-power of a vacuum carbon tube black body was measured for a temperature range from 1800° K. to 2600° K. Conditions were not as steady, and hence the accuracy was not as great at the higher temperatures as at the lower.

Diaphragms were located within the heater tube so as to make it as nearly black as possible. The limiting diaphragm was about 5 mm. for part of the work and 4 mm. for the remainder. These limiting diaphragms were so located that no radiation reached the photometer excepting from the central diaphragm within the furnace tube. The temperature of the carbon tube furnace was measured with an optical pyrometer which had been calibrated by direct comparison with a platinum-wound black body held at the temperature of melting palladium. Higher temperatures were measured by extrapolating by means of Wien's equation, using sectored disks.

When making the intensity measurement at any given temperature of the black body the comparison lamp was set at an approximate color match and the candle-power of this comparison lamp was subsequently measured in terms of carbon lamp standards from the Bureau of Standards. Check values of the candle-power were made at two low temperatures (1710° K. and 1820° K.) from a platinum-wound black body. These checked the values from the carbon tube furnace within the limit of error.

The results at the different temperatures are given in the table. While further experiments now under way may show changes, the results given are probably correct to within ten degrees through the range.

Having the candle-power of the black body at a definite temperature makes it possible to calculate the mechanical equivalent of light for the wave-length of greatest visibility (0.555μ.) If M represents the mechanical equivalent in lumens per watt, F the luminous flux per cm.[2] for the black body expressed in lumens ($=4\pi \times$ mean spherical candle-power), H_λ the visibility of radiation, and E_λ the distribution of energy in the black-body radiation for a particular temperature, we have $M\int_0^\infty H_\lambda E_\lambda \, d\lambda = F$. For H_λ the values obtained by Nutting, together with the values previously determined in this laboratory, were used. Determining E_λ by Wien's equation where $C_1 = 3.8 \times 10^{-12} \frac{\text{watts}}{\text{cm.}^2}$, $C_2 = 1.4460$, M was determined for four different temperatures. The average of the results thus obtained is 760 lumens per watt as the mechanical equivalent of light for the wave-length of greatest visibility.

Brightness of a Black-body Furnace at Various Temperatures.

Temperature	Candles per mm.²
1700° K.	0.053
1800	0.113
1900	0.244
2000	0.45
2100	0.80
2200	1.46
2300	2.48
2400	3.82
2500	6.0
2600	8.8

Practically Silent Railroad Wheels. ANON. (*Scientific American*, vol. cxiv, No. 7, February 12, 1916.)—Despite the number of attempts made in the past to produce a really silent wheel for railroads, no successful wheel of this type has been generally adopted by the railroad companies. In the course of long-continued tests there always cropped out disadvantages which the inventor had overlooked in the design of his wheel. At the present time, however, eastern railroad officials are greatly interested in the performances

of a new type of wheel which has been undergoing severe tests and subjected to nearly a year of actual service.

The new wheel consists of two distinct parts: a hub surrounded by a tread casting. These two members are separated by a space concentric with the periphery into which a cushion of rubber is inserted. Reëntrant curves at intervals are provided to prevent creeping. Among the advantages claimed by the inventor, and so far borne out by tests made in Portland, are the following: Several times the tire service of an ordinary cast-iron wheel; tires are easily removed and renewed; wear of the cushion proper is estimated at four years on average trolley service; steam railroad tests indicate its good influence on the rolling stock, rails, and switches; on city and inter-urban trolley lines the question of excessive noise is solved to the satisfaction of residents along the routes; greatly-improved riding qualities of the cars and greater comfort for the passengers.

A Hydraulic Analogy of the Wheatstone Bridge. R. S. WHIPPLE. (*Proceedings of The Physical Society of London*, vol. xxviii, part i, December 15, 1915.)—The analogy of the flow of water along pipes is frequently used when teaching Ohm's law, but the author does not know of a published description of a simple model. About 18 years ago Professor Callendar showed a model of a Wheatstone bridge in which the arms of the bridge consisted of small capillary tubes through which a stream of gas or air could be passed. The galvanometer, or differential pressure indicator, as it was in this case, consisted of a mica vane pivoted in such a manner that it was deflected whenever the pneumatic pressure became greater on one side of the vane than on the other. By means of taps and tubes of various lengths Professor Callendar was able to show the effect of increasing or diminishing the length of pipe through which the gas passed. The objection to the pneumatic model from the teacher's point of view is that the pressure indicator is difficult to make, and that all the taps require good workmanship. In the model shown, glass and India-rubber tubing with some glass taps are all that are required. The solution used is water colored with ink, and this is allowed to flow slowly through the bridge circuit.

The galvanometer or detector is simply a large air bubble in a horizontal glass tube placed across the bridge arms. A tap is placed in the tube for adjusting the size of the bubble. When the capillary resistance of the tubing on each side of the bridge is equal, the bubble is stationary in the centre of the tube. As soon as the balance of the bridge is disturbed by either partially closing a tap or by introducing another length of tubing by the opening of a tap, the want of balance is shown immediately by the movement of the air bubble. Balance is restored by introducing or diminishing the resistance in the opposite arm of the bridge, and the bubble at once takes up its null position.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

RÖNTGEN-RAY SPECTRA.

By A. W. Hull.[1]

This article is a first report of work upon the accurate measurement of the quality and intensity of X-rays from a standard and exactly reproducible X-ray tube.

A Coolidge tube is excited by a voltage of 100,000, boosted from the 150-volt, 2000-cycle alternating current of the mains by a transformer, and rectified by kenotrons. Oscillations are smoothed out by inductance and capacity until the voltage variations are less than a per cent. for 5 kilowatts and are still smaller for loads below 5 kilowatts.

The spectrometer is of the usual form, with a crystal of rock salt or Iceland spar substituted for the prism, and an ionization chamber in place of a photometer.

Wave-length and intensity values for the X-ray spectra from a tungsten target at five different voltages from 20,000 to 40,000 are plotted, and show a very rapid decrease in wave-length, with rise in voltage, and at the same time an increase in intensity for all wave-lengths. Hence a penetrating ray free from soft radiations can be obtained only by using a filter exhibiting selective absorption for the latter. Measurements of the spectrum at 70,000 volts with and without a filter of 3 mm. of aluminum indicate that the intensity of the soft rays has been reduced much more than that of the penetrating, but there is still a great deal of the former left. Use of still heavier filters to further reduce the intensity of soft rays would also cut down the intensity of the penetrating rays to a small fraction, but with a very powerful tube, such as in process of development, there may yet be left sufficient for practical work. It is also hoped that by use of some special target material giving a powerful radiation of a particular wave-length it may be possible to obtain still purer "monochromate"

* Communicated by the Director.

[1] *American Journal of Röntgenology,* 2, 893–9, December, 1915.

rays of high penetration. It is the wave-length that determines penetration, therapeutic action, and all other effects, and, with rays having the same spectrum, the only variable is milliampère-minutes.

Any spectrum obtained with constant voltage may be duplicated with fluctuating voltage by using a definite but different voltage and current, but the conversion factors must be known and will be large for machines differing greatly in wave-form.

The principles upon which the work is based, the operation of the spectrometer, and the method of obtaining constant voltage are explained in detail, with diagrams, curves, and oscillograms.

MAXIMUM FREQUENCY OF X-RAYS AT CONSTANT VOLTAGES BETWEEN 30,000 AND 100,000.

By A. W. Hull.[1]

MEASUREMENTS taken from curves of the energy distribution in the X-ray spectra at constant potentials determined with an accuracy of 3 or 4 per cent. by means of the spectrometer show that the maximum frequencies for voltages up to 100,000 are given accurately by the quantum relation; that is, they are proportional to the voltage. There is no tendency for the frequency to fall off at the higher voltages, such as Rutherford reported from work by the absorption method, and no indication that such falling off will occur at still higher voltages than those studied. At 95×10^3 volts the maximum frequency observed was 22.8×10^8.

NEGATIVE RESISTANCE.

By A. W. Hull.[2]

APPLICATION of the principles of electron emission in high vacuum has produced a device having all the characteristics of a true negative resistance. It consists of a hot filament cathode and plate anode, with an interposed perforated plate, or grid, maintained at a constant potential higher than the plate. This grid carries away the secondary electrons produced by bombardment

[1] *Physical Review*, 7, 156–8, January, 1916.

[2] *Physical Review*, 7, 141–3, January, 1916.

of the plate. As the velocity of the primary electrons from the filament increases, with increase of potential gradient from filament to plate, the secondary emission from the plate increases, slowly at first and then more rapidly, finally exceeding the primary when the net result at sufficiently high voltage is a loss of electricity from the plate. Consequently the current to the plate with rising voltage increases at first slowly up to a certain value, and then falls off rapidly, just as would occur with a negative resistance in circuit. This phenomenon is completely reversible, has no appreciable lag, and is aperiodic.

Typical of the many scientific applications of this apparatus is its use connected in series with a positive ohmic resistance, when it acts as an extremely sensitive amplifier of voltage changes across the terminals of the combination. Preliminary tests have given an amplification of 100-fold, and there should be no difficulty in going to 1000- or 10,000-fold.

SUMMARY OF PHYSICAL INVESTIGATION WORK IN PROGRESS ON (X-RAY) TUBES AND ACCESSORIES.

By W. D. Coolidge.[1]

THIS article is an illustrated discussion of the objects, progress, and outlook of some of the X-ray researches being prosecuted in the Research Laboratory. The following points are considered in detail:

Target design for sharp definition, requiring uniform energy distribution and cooling of the focal spot. Materials, water-cooling, constant current excitation, rotation, focussing of cathode rays.

Hooded target to cut out secondary radiations.

Reduction of size of bulb to 4 inches at least.

Tipless bulb.

High potential tube with hooded and water-cooled target. Current supply and voltage regulation. Transformer requirements.

Exact control of filament temperature.

Measurement of tube voltage.

[1] *American Journal of Röntgenology*, 2, 881–92, December, 1915.

HEAT CONDUCTIVITY OF TUNGSTEN AT HIGH TEMPERATURES AND THE WIEDEMANN-FRANZ-LORENZ RELATION.

By Irving Langmuir.[1]

CALCULATIONS based upon the previously-measured[2] resistance and power radiation of a tungsten filament between 600° and 2800° K. have led to the development of a differential equation to express the temperature distribution along a filament in the neighborhood of a cooling junction, from which values of the ratio of the temperature at the cooling junction to that at a point so far removed as to be unaffected by the junction can be calculated with any desired accuracy of approximation.

Recalculations from Worthing's data on the heat conductivity of tungsten at high temperatures[3] have shown that his experimental results are quite consistent with the assumption that the heat conductivity is practically independent of temperature. The value at 2410° K. from these data is 1.14 watts per centimetre per degree.

Allowing a temperature coefficient, as suggested by the work of Jaeger and Dieselhorst, tungsten fits in with the Wiedemann-Franz-Lorenz relation as well as do most other pure metals.

RADIATION FROM TUNGSTEN FILAMENTS AND THE MECHANICAL EQUIVALENT OF LIGHT.

By Irving Langmuir.[4]

FROM careful measurements on fifteen special lamps, of volts, ampères, candle-power, and temperature, corrected for the cooling effect of leeds, and of length and diameter of filaments, the following quantities were calculated for some 19 different temperatures between 273° and 3540° K.:

1. Specific resistance.
2. Resistance exponent, $n_R = d \log R / d \log T$.

[1] *Physical Review*, 7, 151–2, January, 1916.
[2] *Ibid.*, 7, 152–4, January, 1916.
[3] *Ibid.*, 4, 538 (1914).
[4] *Ibid.*, 7, 152–4, January, 1916.

3. Watts radiated per unit surface.

4. Watts exponent, $n_w = d \log W/d \log T$ where W = watts radiated at 0° K.

5. Total emissivity. (Watts radiated as fraction of total radiation from a black body at the same temperature.)

6. Intrinsic brilliancy per square centimetre of projected area.

7. Color expressed as temperature of a black body which emits light of the same color.

The mechanical equivalent of light, using Nutting's visibility data and taking as constants of the Planck equation

$$C_1 = 3.72 \times 10^{-21} \text{ watts}$$
$$C_2 = 1.4392$$

was found to be 0.00121 watt per lumen, compared with Nutting's value of 0.00120, and that of Ives, Coblentz, and Kingsbury, 0.00162. If the last value is correct, either the emissivity of tungsten for $\lambda = 0.55$ should be 0.67 (instead of 0.50) or the melting-point must be at least 3750° K., both of which suppositions are wholly inconsistent with the observations.

The methods of measurement are stated and a table of the numerical results given.

The Production of Ammonia from Cyanamid. W. S. LANDIS. (*Journal of Industrial and Engineering Chemistry*, vol. 8, No. 2, February, 1916).—The large number of installations operating with perfect success in various parts of the world for a number of years have demonstrated the commercial possibility of making ammonia from lime nitrogen. The plant, in its present highly-developed state, is extremely certain in its action and simple to operate. The efficiency obtained in the transformation of the nitrogen in lime nitrogen into ammonia gas is upward of 98 per cent. The consumption of reagents is remarkably small, and they are cheap and easy to obtain in all parts of the world.

The quality of the ammonia produced by this process is not surpassed by any in the United States. It is chemically pure as produced, and requires no further costly and tedious purification to render it available for the highest grade chemical products or for the production of the liquefied anhydrous product. The actual cost of production of this high-grade pure ammonia on a considerable scale, which enables one to take advantage of the lower price at which lime nitrogen is offered, brings high-grade cyanamid-ammonia into the market almost as cheaply as the most impure forms already found there, and very much cheaper than it is possible to obtain an equal quality of ammonia from gas-house liquor, the coke ovens, etc.

An Investigation on the Transmission, Reflection, and Absorption of Sound by Different Materials. F. R. WATSON. (*The Physical Review,* vol. vii, No. 1, January, 1916.)—The apparatus employed in the experiments on the transmission of sound consisted of an adjustable whistle for a sound source, mounted at the focus of a parabolic reflector with a focal length of nine inches and an aperture of five feet. This was placed in front of an open doorway, so that the sound, which proceeded in a large bundle from the reflector, could pass through the doorway into another room. The receiver of sound, a Rayleigh resonator, was mounted in the other room in the path of the sound symmetrically opposite the reflector and doorway, and measured the intensity of the transmitted sound.

The resonator used is a modification of Rayleigh's original design. It consists of a horizontal brass tube closed at one end by an adjustable piston. A mica disk is suspended by a quartz fibre at an angle of 45° with the axis of the tube. When the sound of the whistle reached the resonator, it set up a back-and-forth surging of the air in the resonator and caused the mica disk, which was placed at the loop, to rotate. This action is in accordance with the general principle that any flat object in a current of air tends to set itself at right angles to the current. The amount of rotation was measured by means of a lamp and scale in connection with a mirror which was attached to the suspended system above the mica disk. Measurements were taken, first, through the open doorway, then with one panel of material placed over the doorway, then two panels, and, finally, three panels, the deflection of the resonator being noted for each case.

The results show that ½-inch hairfelt stops less sound than other materials, one layer stopping only 43 per cent. Next comes ¼-inch cork board, which stops 80 per cent. for one layer and 90.5 per cent. and 92.6 per cent. for two and three layers respectively. This is followed by ¾-inch paper-covered hairfelt, ¾-inch flaxboard, and, finally, ¼-inch pressed fibre, one layer of which stops practically all the sound.

The transmission of sound of constant pitch depends on at least three qualities of the transmitting material: its porosity, density, and elasticity. Porous bodies transmit sound in much the same proportion that they transmit air. This is why the hairfelt transmits more sound than the other samples. Density also plays a part. Two materials stop sound in proportion to their densities, other conditions being equal. Thus the pressed fibre stops more sound than the same thickness of cork, because it is heavier. Finally, an elastic body may transmit sound if it happens to be in tune with the source in sound so as to vibrate in unison with it. When the pitch of the sound varies, porous walls and elastic walls reflect high-pitched sounds in greater degree than low-pitched ones.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, February 16, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

Mr. Charles E. Bonine, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The standing committees for the year 1916–17 were announced.

G. E. deSchweinitz, Esq., M.D., LL.D., of Philadelphia, presented the paper of the evening, entitled "Drug and Occupational Amblyopias."

Consideration was given to the deleterious effects on the visual apparatus caused by the abuse of tobacco and alcohol, and particular reference was made to the dangers of wood-alcohol as it is employed in the various trades and as it is abused when employed as an adulterant and to take the place of grain-alcohol, particularly in cheap grades of essence of peppermint, bay rum, etc. The dangers to the ocular apparatus of those who work in lead, bisulphide of carbon, nitrobenzol, and dinitrobenzol were described, as well as the visual disturbances caused by the ingestion of large doses of quinine, salicylic acid, and certain arsenic preparations, notably atoxyl. The lecture was illustrated by numerous lantern slides, showing the lesions in the ocular apparatus and charts of the visual field.

After a brief discussion the thanks of the meeting were extended to Dr. deSchweinitz.

Adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1916.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Alfred W. Gibbs, Chairman,
Kern Dodge,
W. C. L. Eglin,
George R. Henderson,
George D. Rosengarten.

ENDOWMENT.

Henry Howson, Chairman,
Alfred C. Harrison,
Richard Waln Meirs,
Coleman Sellers, Jr.,
William Chattin Wetherill.

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Charles Day,
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Alfred C. Harrison,
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William Chattin Wetherill.

MEETINGS.

Gellert Alleman,
Charles Baskerville,
G. H. Clamer,
George R. Henderson,
Herbert E. Ives,
A. E. Kennelly,
Edwin F. Northrup,
M. M. Price,
James S. Rogers,
George D. Rosengarten.

MUSEUMS.

Emile Berliner,
Charles F. Brush,
Arthur L. Church,
Henry F. Colvin,
Charles Day,
George A. Hoadley,
Henry Howson,
A. E. Outerbridge, Jr.,
Coleman Sellers, Jr.,
Thomas Spencer.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, February 2, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1916.

MR. G. H. CLAMER *in the Chair.*

Mr. C. E. Bonine was unanimously elected Chairman for the year 1916.

The following reports were presented for first reading:

No. 2654.—Circle Drawing Attachment for Microscopes.

No. 2655.—Prepayment Gas Meter.

The following reports were presented for final action:

No. 2626.—Dorr's Hydrometallurgical Apparatus: the Dorr Classifier, the Dorr Thickener, and the Dorr Agitator. John V. N. Dorr recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2634.—Cement-Gun. Carl E. Akeley recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 10, 1916, at 8 o'clock P.M., with Dr. Robert H. Bradbury in the chair. The minutes of the previous meeting were approved.

Charles Baskerville, Ph.D., F.C.S., Professor of Chemistry, College of the City of New York, presented a paper on "Refining of Animal and Vegetable Oils." Dr. Baskerville described the process at present in use for refining vegetable oils by neutralizing the free fatty acids in the crude oil, usually by agitating the oil with an aqueous solution of an alkali, and then heating the mixtures during agitation until the oil "breaks." The mass is then allowed to stand until the "foots" settle and the oil drawn off by means of a siphon. He then demonstrated a new process for increasing the speed of refining and also for increasing the quantity of refined oil and at the same time reducing to a minimum the amount of oil entrained in the "foots." The subject was illustrated by several experiments.

After a brief discussion, a vote of thanks was extended to the lecturer and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, February 3, 1916, at 8 P.M.

Mr. Charles Day and Professor Fernald presided jointly.

Mr. Day introduced Arthur M. Greene, Professor of Mechanical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y., who presented a paper on "The Development of the Pumping Engine."

The lecturer described the earliest devices for raising water, and traced the development of pumping apparatus from ancient times to the present day. Consideration was given to the inventions and improvements of Hero, Savery, Newcomen, Watt, Bull, Worthington, Reynolds, Gaskill, d'Auria, and others, and the special contributions of each to the perfection of the apparatus were pointed out. The modern requirements of a pumping engine were outlined and recent large installations were described. The subject was illustrated by one hundred lantern slides.

After a brief discussion, a vote of thanks was extended to Professor Greene.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

(Stated Meeting, Board of Managers, February 9, 1916.)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

Mr. John B. DeCoursey, The Gladstone, Eleventh and Pine Streets, Philadelphia, Pa.

Mr. George A. Dunning, refrigerating engineer, Standard Ice Manufacturing Company, Twenty-seventh and South Streets, Philadelphia, Pa.

Mr. James Elverson, publisher, *The Philadelphia Inquirer,* Philadelphia, Pa.

Mr. Frank H. Sauer, draftsman, 1307 Atlantic Avenue, Camden, N. J.

NON-RESIDENT.

Mr. A. Stuart Baldwin, chief engineer, Illinois Central Railroad Company, Chicago, Ill.

Mr. E. W. Lloyd, general contract agent, Commonwealth Edison Company, Edison Building, Chicago, Ill.

Mr. S. S. Riegel, mechanical engineer, The Delaware, Lackawanna and Western Railroad Company, Scranton, Pa.

CHANGES OF ADDRESS.

Mr. Charles O. Bond, 7008 Greene Street, Mt. Airy, Philadelphia, Pa.

Mr. Justice C. Cornelius, 712 Ferry Street, Easton, Pa.

Dr. Ernst Fahrig, 720 Metropolitan Avenue, Atlantic City, N. J.

Mr. John B. Rumbough, P. O. Box 2, Asheville, N. C.

Mr. David H. Wilson, Jr., Wilson Welder and Metals Company, Vanderbilt Avenue and Forty-fifth Street, New York City, N. Y.

NECROLOGY.

Mr. Coleman L. Nicholson, 117 Argyle Road, Ardmore, Pa.

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BOOK NOTICES.

THE METALLOGRAPHY AND HEAT-TREATMENT OF IRON AND STEEL, by Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University and The Massachusetts Institute of Technology. Second edition. Cambridge, Sauveur and Boylston, 1916. 504 pages, 438 illustrations, 8vo. Price, $6.

This is a new edition, revised and enlarged, of Professor Sauveur's "Metallography of Iron and Steel," published in 1912, a comprehensive review of which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE, February, 1913. The author states that 50 pages of new matter and nearly 100 new illustrations have been added in this revision.

Careful comparison of the first and second editions shows that practically the same arrangement of matter and illustrations has been retained, substituting the word "Chapter" for "Lesson" in each subdivision and transferring the instructions regarding "Manipulation and Apparatus" from the Appendix in the first edition to Chapters II and III in the new edition.

For those who do not already possess the first edition this new edition will prove invaluable not only to students of metallurgy but also to practical workers in the field which it covers so fully.

There has been an unexpectedly great enlargement of need for such a thoroughly up-to-date book in this country since the first edition appeared, shortly before the outbreak of the European war, for very many establishments have obtained large contracts for metallurgical products requiring most careful and accurate heat-treatment.

A new edition of this classic is therefore timely.

ALEX. E. OUTERBRIDGE, JR.

A HANDBOOK OF COLLOID-CHEMISTRY: THE RECOGNITION OF COLLOIDS, THE THEORY OF COLLOIDS, AND THEIR CHEMICO-PHYSICAL PROPERTIES, by Wolfgang Ostwald. First English edition, translated from the third German edition by Martin H. Fischer, assisted by Ralph E. Osper and Louis Berman. Philadelphia, P. Blakiston's Son & Co., 1915. 266 pages, illustrations, 8vo. Price, $3.

It is a question of literary taste whether the German word "Handbuch" may not be better rendered by the word "Manual," or even whether the simple title "Colloid-Chemistry" would not have been enough. However, the

reviewer is not concerned with these details, but with the merits of the book and scope of it. It is, indeed, hardly necessary to criticise. One may be sure that the volume will be found to be a comprehensive and authoritative exposition of the field to which it is devoted, and the principal points to which examination of the English edition should be directed are the correctness of the translation and the adherence to the English idiom. The work seems entirely satisfactory in these respects. There is a gratifying lack of awkward phrases that are so often found in works translated from the German.

A summary of the tables of contents will give an idea of the scope of the work. Under the head of General Colloid-Chemistry are discussed: Relations between physical state and general properties; general energetics of the dispersoids; distribution of the colloid-state and the concept of colloid-chemistry. Under the head of Special Colloid-Chemistry are discussed: Relations of volume and mass in colloids; movement in colloid systems and its results.

Dr. Fischer, in his preface, refers to the fact that the problems of colloid-chemistry are nowadays more to the fore than those of the crystalloids. This is probably due to the fact that the crystalloid condition is essentially one of rest, while the colloid condition is one of action. He also expresses, not unnaturally, astonishment at the fact that seven years and three large German editions of this work were required before it appeared in the language of Thomas Graham and the brilliant group of modern English-speaking colloidists.

The book has a portrait of Thomas Graham as a frontispiece, and is well printed. It is scarcely necessary to say that it will at once take front rank among the works available in English to the student of this important, complex, and rapidly-growing field of science.

HENRY LEFFMANN.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS, by Emil Hatschek. Philadelphia, P. Blakiston's Son & Company, 1916, 102 pages. Second edition. 17 illustrations, 12mo. Price, $1.

This is an excellent summary of the facts and theories concerning colloids and can be read almost at one sitting (not "setting," as the author gives the word on page 17). In the preface to the first edition, which is reprinted in the present issue, it is stated that the work is essentially a republication of articles that appeared in the *Chemical Trade Journal*, based on lectures delivered at the Sir John Cass Technical Institute, to an audience composed of students in many departments of chemistry and of widely different degrees of preparation, hence the necessity for a distinctly elementary treatment of the topics. In the present issue the work has been increased by an appendix on technic.

The book is well printed, and a perusal of it will give much important information to that numerous class of chemists who began their studies in the third quarter of the last century, when Graham's work was new and "Chemical Physics" was a mere side-issue in science. HENRY LEFFMANN.

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Catalysis and its Industrial Applications, by E. Jobling, A.R.C.Sc., B.Sc., F.C.S. Reprinted from *The Chemical World*. 120 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, in cloth, $1.

An Introduction to the Physics and Chemistry of Colloids, by Emil Hatschek. Second edition, 107 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, in cloth, $1.

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U. S. Bureau of Mines, Technical Paper 108, Shot Firing in Coal Mines by Electricity Controlled from the Outside, by H. H. Clark, N. V. Breth, and C. M. Means. 36 pages, 8vo. Washington, Government Printing Office, 1915.

The Periodic System and the Properties of the Elements. W. D. HARKINS and R. E. HALL. (*The Journal of the American Chemical Society*, vol. xxxviii, No. 2, February, 1916.)—In this paper a periodic table has been presented which shows graphically the relations between the main and the sub-groups of elements. The main defect of the periodic tables which have been designed formerly is that they do not show these relations correctly. The table arranges the elements in the exact order of their atomic numbers, and gives no blanks for unknown elements which do not correspond to atomic numbers as determined by Moseley's work on the X-ray spectroscopy of the elements. It also plots the elements according to their atomic weights, so the isotopic forms of an element may be shown graphically on the table, and the alpha and beta decompositions of the radio-active elements may also be plainly depicted. Both the zero and the eighth groups fit naturally into the system.

The table may be best represented as a helix in space, but may be shown as a spiral in a plane. The space form is represented by its vertical projection on a plane, but drawn with line perspective so that it may be easily visualized.

CURRENT TOPICS.

Development of the Incandescent Lamp. From "Light and Illumination," C. P. Steinmetz. (*Journal of the Western Society of Engineers,* vol. xx, No. 9, November, 1915.)—All the advance made in illuminating engineering has been made by utilizing higher and higher temperatures. Attempts at producing light by the electric current were made by heating wire conductors to a high temperature, and the first attempt at an incandescent lamp was with a platinum wire; but platinum melts at about 1760° C., and the efficiency of light production by this means was very low. Then Edison discovered that a wire of carbon—a carbon filament—could be used in the place of platinum. Carbon does not melt or boil until a temperature of about 4000° C. is reached. Consequently it should withstand a much higher temperature in an incandescent lamp than platinum. The old carbon filament lamps were run at about 1800° C., somewhat above the melting-point of platinum, and thus with higher efficiency and no danger of melting. About 45 watts of electrical energy were required per candle-power.

Higher temperature and correspondingly better efficiency were limited, not by the melting or the boiling of the filament, but by another limitation—evaporation. The carbon filament, much below its melting- and boiling-point, slowly evaporated, the carbon vapor being deposited on the lamp bulb. With continuous evaporation the filament became thinner; thereby the temperature lowered and the light became less. The deposited carbon vapor also obstructed the light. The operating temperature of the old carbon filament lamp is therefore limited to a value where the rate of evaporation does not unduly reduce the light production within a reasonable time of, say, 500 hours or so.

The material obtained by carbonizing the bamboo fibre employed in incandescent lamps evaporates rather rapidly, but carbon deposited from gasoline at high temperature does not evaporate so easily and can be used at higher temperatures. A higher efficiency was therefore obtained by depositing a shell of carbon from gasoline vapor upon the carbon filament produced from fibre.

The carbon filament of the old incandescent lamp evaporated, although it was operated at a temperature much below the boiling- and melting-point. Tungsten, on the other hand, can be run nearly at the temperature of the melting-point with very little evaporation. Osmium proved very efficient as an illuminant in a lamp, but is too rare to be generally used. Tantalum gave good results, having a higher resistance than carbon, but it has been superseded by tungsten,

because the melting-point of the latter is much higher and is now used in all lamps having metallic filaments. The so-called "Mazda" is a tungsten lamp and requires one watt per candle, while the carbon lamp requires three watts per candle.

In the carbon and tungsten lamps a vacuum has been used. Naturally the lamp having a carbon filament must at least be exhausted of air to prevent its combustion, but that is not the fundamental reason for the vacuum, because the lamp bulb might be filled with a gas in which carbon will not burn, such as nitrogen, hydrogen, or argon. But to maintain the carbon filament in such a gas at the temperature it would have in a vacuum would require much more energy. The use of a vacuum, however, is disadvantageous, because it facilitates evaporation, and thus sets a lower and less efficient limit to the temperature to which in practice the filament should be raised, even though far below the melting- or boiling-point.

Assume the evaporation in a vacuum to be such as to limit the life of the lamp to 1000 hours at the temperature produced by 100 watts, then with nitrogen at atmospheric pressure we could use, say, 200 watts with the same rate of evaporation and blackening. But this would raise the temperature, so that, while 100 watts will give 200 candles, 200 watts would give 600 candles, were it not for the heat carried away by the nitrogen from the filament. Consequently an additional 100 watts must be supplied to make up for this loss and raise the temperature sufficiently to give the 600 candles. In this way the candle-power of the lamp has been increased from 200 candles with an expenditure of 100 watts to 600 candles for 300 watts with the same evaporation, blackening, and life, which means an increase in efficiency over the vacuum lamp from one candle per watt to two candles per watt.

The Density of Lead from Radio-active Minerals. T. W. RICHARDS and C. WADSWORTH, 3D. (*The Journal of the American Chemical Society*, vol. xxxviii, No. 2, February, 1916.)—The starting differences observed by several investigators in the atomic weight of lead from radio-active sources obviously suggest that other properties also may vary in different specimens; and the comparison of these may be of service in tracing the true causes of the differences in atomic weight. The phenomena are of interest whether or not one accepts the plausible hypothesis of Soddy and Fajans concerning the "isotopes." In a new field of this sort as great a variety of facts as possible is peculiarly important.

The densities of ordinary lead (having an atomic weight of 207.2) and of lead from Australian radio-active sources (having an atomic weight of 206.3) were carefully determined in a convenient pycnometer which is described in detail for the first time, although long in use. The density of ordinary lead reduced to the vacuum

standard was found to be 11.337, and that of radio-active lead, 11.288. Continued fractionation produced no change in this low density, and it could not have been due to any irregularity in preparing the metal, since the samples were all prepared in the same way. This difference in density is especially interesting because it almost exactly parallels the difference in atomic weight. Thus the atomic volume of radio-active lead is found to be almost exactly equal to that of ordinary lead, the figures being each nearly 18.28.

Turbo Blowers and Compressors. H. L. GUY and P. L. JONES. (*Proceedings of The South Wales Institute of Engineers,* vol. xxxi, No. 5, January 16, 1916.)—Perhaps the most marked feature in the history of power production has been the replacing of reciprocating machinery by that of rotary type. The steam turbine has invaded and captured a considerable portion of the fields of usefulness of the reciprocating steam engine. The centrifugal water-pump has replaced the reciprocating pump; rotary condensed auxiliaries are rapidly superseding reciprocating plant, and rotary air blowers and compressors have entered into successful contest with reciprocating compressors. The principal factors which have decided the issue in favor of the rotary plant are: small space, excellent balance, and low first cost and maintenance. Machinery of this type has the additional and valuable advantage that a mixed pressure turbine can be employed utilizing waste steam, a large quantity of which is usually available.

The turbo blower is really a multi-stage centrifugal air-pump consisting essentially of several pumps driven by a common spindle, with the outlet of one discharging into the intake of the next. Although the operation is very similar to that in a centrifugal water-pump, there are important differences in the two classes of machines. (1) For a given peripheral speed, the terminal pressure is proportional to the density of the medium, hence the pressure produced in the impeller of the blower is about 1/800 of the pressure that would be produced with water, water being 800 times as heavy as air. For this reason it is always necessary to build blowers, even with such low terminal pressures as 5 pounds per square inch, with more than one impeller, and for the more usual pressures of from 8 to 15 pounds per square inch it is necessary to employ three, four, or even five stages. (2) In a water-pump the density remains constant, and therefore the increase in pressure per stage is constant, but in a blower the pressure and temperature of the air change, resulting in a change in density, so that the increase in pressure per stage is continually increasing. Turbo compressors are identical with turbo blowers in principle and operation and usually deliver air at pressures between 50 and 100 pounds per square inch. Stating the efficiency as the ratio of work actually done to that necessary with isothermal compression, an efficiency of 60 to 66 per cent. can be obtained.

Blue Bulb Electric Lamps in Photography. ANON. (*Bulletin Engineering Department, National Lamp Works of General Electric Company*, No. 26, December 30, 1915.)—The short exposure required in portrait and motion-picture photography demands a high intensity of actinic light. At the same time, in order that the reproduction of facial expression may be natural, the brightness of the light should not be so intense as to cause the subject to squint. These contrary requirements led to the development of a special blue-grass bulb for 1000-watt Mazda C. lamps, which is known as the "photographic-blue" bulb. This bulb screens out about two-thirds of the light emitted by a Mazda C. lamp filament, but it transmits, as shown by spectograms, all those rays which are actinic to those green- and yellow-sensitive emulsions that are usually called orthochromatic. Furthermore, the light from the photographic-blue bulb Mazda C. lamp appears like daylight, and its ordinary-emulsion actinicity per candle-power is so nearly equal to that of daylight that it may be mixed with daylight without any allowance being made in judging the proper time of exposure. This is an important quality, for it enables the photographer to estimate amounts of exposure by the brightness of the subject in accordance with his usual practice. Obviously, these advantages, namely, the reduction in brightness and likeness to daylight, can be utilized to the fullest extent with ordinary emulsions, and, since most portrait and motion-picture photographs are made on such emulsions, the photographic-blue bulb is particularly adapted to the illumination of the usual studio.

Peat Powder Used by Sweden for Locomotives. ANON. (*U. S. Commerce Report*, No. 40, February 7, 1916.)—Experiments in the use of peat powder on locomotives of the state railways have demonstrated that as heavy trains can be pulled and as good speed be made where this fuel is employed as where anthracite is used, according to a statement issued by the Swedish Telegram Bureau, which has been received from the secretary of the American Embassy at Stockholm. The statement declares that the powder can technically as well as economically take the place of anthracite as fuel for locomotives.

The railway directors have decided to undertake the development of this class of fuel by two different methods for purposes of comparison. Two experts have been requested to give complete estimates of the cost of preparing a certain bog for the manufacture of peat powder, together with estimates of running expenses, by the respective methods. The bog selected is said to be that at Hasthagen, about one and one-half miles from the station at Vislanda, with an area of about 500 acres.

The Regeneration of Sulphated Storage Cells. G. A. PERLEY and C. W. DAVIS. (*The Journal of Physical Chemistry*, vol. xx,

No. 2, February, 1916.)—The authors have previously shown that sulphated storage cells can be regenerated satisfactorily if the battery acid is replaced by a solution of sodium sulphate. Upon the passage of a normal charging current, the lead sulphate is reduced within sixty hours, even on badly-sulphated grids. This method has since been tried by others with uniformly good results. It was conceivable that some other salt might give deposits that were enough better to justify its use, and, accordingly, some experiments have been made with other sodium salts.

The experiments point to the following general conclusions: (1) Sodium sulphate is the best salt to use in regenerating positive and negative storage-battery grids. (2) Dummy positive grids on the outside of the negative plates diminish the time of reduction. (3) Hydrolysis of the lead salts formed in sodium hydroxide solution yields large and troublesome quantities of lead monoxide. The active material of the grids is removed to a considerable extent. (4) With sodium sulphite solutions, a hard crystalline lead is deposited at the cathode which causes buckling of the grids. (5) Reduction in whole or in part of a sulphated grid results by the use of a solution of sodium sulphate, carbonate, phosphate, or sulphite. (6) Good anode deposits from sulphated grids can be obtained only with sulphate, carbonate, and hydroxide solutions. Relatively high anode corrosion with sodium hydroxide solutions makes these useless.

Ignition of Explosive Gas Mixtures by Electric Sparks. J. D. MORGAN. (*The Journal of the Institution of Electrical Engineers*, vol. 54, No. 254, January 15, 1916.)—A common method of defining the least spark which will ignite a given gas mixture is by specifying the number of volts and ampères, or the number of ampères and the inductance in the circuit prior to the formation of the spark. On the assumption that this gives a measure of the ability of a spark to ignite a gas (or the " incendivity " of the spark), the validity of the method has been rightly questioned. Nevertheless, there is value in the method in indicating the practical conditions under which sparking becomes possible.

An experiment bearing on the subject consists in so adjusting the spark-gap between a pair of pointed poles in the high-tension circuit of an induction coil that in neither air nor coal-gas alone can a spark pass, but the poles emit a faint blue glow or brush discharge visible in the darkness. If the poles are contained in a small chamber into which an explosive coal-gas and air mixture is introduced, it is found that after an interval which varies with the size of the gap the gas explodes. The time can be made to vary from the fraction of a second to as much as two minutes. If the gap is too large, no explosion can be produced; when the explosion-flame appears, a spark at once passes, due to the greater electric conductivity of the ionized gases, and often persists a second or two after the flame has vanished. The

spark appears to be the consequence and not the cause of the explosion.

Experiments such as this suggest the ionic origin of ignition. It has been shown that when a hot wire or spark is the source, ignition only occurs when ionization is produced, and ionization alone without heat has been found to be capable of producing ignition.

The Heat-insulating Properties of Commercial Steam Pipe Coverings. L. B. McMillan. (*Proceedings of The American Society of Mechanical Engineers,* December 7 to 10, 1915.)—Most of the early results of tests of the value of steam pipe non-conducting coverings apply at only one temperature or two, at most, and for one or two thicknesses; they are not applicable to modern conditions involving high superheat and thicker coverings.

The work which this paper describes has been carried on for a period of about two years at the University of Wisconsin, and every effort has been made to secure accurate and consistent results. The effect on heat losses of varying the temperature difference between pipe surface and air between 0° and 500° F. has been thoroughly investigated, and the conclusions reached are fully explained. Different thicknesses of material from 0 to 3 inches were tested, and the laws confirmed by the results of these tests permit their application to any thickness whatsoever; and the drop in temperature from steam in a pipe to the inner and outer surfaces of the pipe wall under various conditions may be accurately determined. Another new fact disclosed is that the loss from any covered pipe is a function of the temperature difference between the surface of the covering and the surrounding air; and that this function is the same for all coverings having the same character of surface, regardless of what the other properties of the covering may be, since the effects, if any, of these properties appear in the temperature difference. The value of the function has been determined for canvas-covered surfaces, and a complete explanation of its significance is included.

Kapok—a New Textile Fibre. J. Boyer. (*Scientific American Supplement,* vol. lxxxi, No. 2094, February 19, 1916.)—A French inventor, M. Jean Mondamert de St. René, has just created a new industry in textiles by discovering a method of carding, spinning, and weaving kapok. This is a silky down from the *Bombax ceiba* or *Eriodendron anfractuosum* (silk cotton trees), which are well distributed in the tropics, especially in the West Indies, South America, and the Soudan. At the moment there are fifty establishments in Java collecting this vegetable wool, while five men have been at work with it alone for about a dozen years.

Javanese kapok is composed of threads of a clear yellow, somewhat silky in texture and one-half to three-quarters of an inch in length, and is contained in the long capasudal fruit of the tree. In the midst of the mass of threads constituting a floss there are to be

found, previous to working it, seeds of an inch to an inch and a quarter in diameter, of dark brown color. On examining the floss with a microscope it is seen to be composed of unicellular fibres of the length above given, cylindrical throughout most of the length, and with thin walls and a light skin near the base. The central tube, filled with air, gives to the fibre its very valuable lightness. Aside from their lightness, the fibres of kapok possess absolute impermeability to water, due, according to Dr. Clavel, to the presence of a wax with which the filaments are coated. This is described by M. de St. René as a "solidified oil," who calls attention to the membranous nature of the covering. However this may be, kapok, through its inaptitude to accept water and the quickness with which it dries, does not rot.

It will support from thirty to thirty-five times its weight in water, while ordinary cork will float only about five times its weight. Experiments have shown that a packet of kapok which sustained thirty-two times its weight when first immersed would still hold up twenty-six times its weight at the end of a month in water. No other vegetable substance known has this extraordinary ratio of flotation power and impermeability: it is an attribute of down *Bombax* alone. On account of its elasticity and its lightness, kapok is admirable for the stuffing of cushions or mattresses, replacing advantageously feathers, wool, or hair. Again, its conduct in the water makes it superior for life-preservers, "cork" jackets and other items for life-saving in rivers of the sea.

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SUPPLYING THE WORLD WITH NEWS.*

BY

MELVILLE E. STONE, LL.D.,
General Manager, The Associated Press, New York City, N. Y.

I HAVE had some doubt as to the precise propriety of my presence here to-night. This institution is given over to the technicalities of the Arts and Sciences. But, on reflection, I think I find some warrant for my intrusion. I am minded that you take your name from that great American, who was not only a notable diplomat, statesman, scientist, and philosopher, but was also, in his day, the Master Printer of the Colonies. And in this room you have, as if ordered for the occasion, side by side, Franklin's original apparatus for the study of electricity, and the imposing stone which he used in his printing office. It is also worthy of mention that another printer who for many years was a valued member of the institution, Mr. William Swain, one of the founders of the *Philadelphia Public Ledger*, was an active co-worker with Professor Morse in developing telegraphy and in fitting that great invention to ministry in the business of news gathering. So, in the words of Paul, I have "waxed confident by these bonds."

As you pick up your daily newspaper, issued to you for the smallest coin that is minted by the Government—filled as it is with a vast bulk of information gathered from every habitable

* Presented at the Annual Meeting of the Institute, held Wednesday, January 19, 1916.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

spot on the globe—if you have anything like an inquisitive mind, your curiosity must be aroused. It must interest you to know how all this so-called "news," good and indifferent, important and trivial, from nearby places and from the uttermost parts, is collected, transmitted, and delivered to you at so small cost. Well, this I shall strive to tell you: not in an oration, nor even in a speech, but in a quiet, fireside talk.

Also, it may gratify you to remember that this business of systematic and comprehensive news-gathering is an American enterprise. It originated here, and here it has reached its most perfect development. The work began in the early days of the last century. Our Revolutionary War had closed and the Federal Government had been successfully established. But great things were happening abroad. Bonaparte, after his unparalleled career of victory, had pushed his conquering squadrons over the continent, had invaded Russia, and was on his way to Moscow. The hour was one pregnant of great possibilities for our infant republic. It was natural that at such a moment there should be an avid call for news from Europe.

It was then that Samuel Topliff, of Boston, entered the field. He took charge of the news-books of the Exchange Coffee House and began a career as a news-gatherer which lasted over thirty years and which, for zeal and efficiency, has rarely been equalled. With a small boat he ran into Boston harbor on the arrival of a European vessel, interviewed the captain, and rushed back to record this latest information in his news-books at the Coffee House. Thither merchants, and later newspaper reporters, repaired, and thus the news was distributed. To hurry this news into and through the country from city to city, fast pony expresses were introduced, carrier pigeons were trained, and rude semaphores, to wig-wag from hilltop to hilltop, were set up. Then, in time, the steamship supplanted the sailing craft, the railroad usurped the functions of the stage-coach and the expresses, and, finally, the electric telegraph displaced the pigeons and semaphores.

Then came the Atlantic cable. All of these instrumentalities were speedily employed for the gathering and distributing of news. And for news the American people at a very early period grew voracious. Away back in April, 1814, Nathan Hale, a nephew of the patriot spy, became editor of the *Boston Adver-*

tiser, and, in his first editorial, said one of the peculiar traits of our national character was the insatiable appetite for news: even the habitual salutation on the meeting of the people was, "What's the news?" We became, and still are, as no others on earth, a news-mad people.

As time moved on, Topliff ceased his activities, which were taken up by others. His methods were adopted in New York harbor, and later, when the Cunard Line made Halifax its first western port of call, that was the centre of interest and source of supply for European information, which was sent to Boston and the other cities of the country by pony expresses, by railway trains, and at last by telegraph.

There is a story of the cable which may interest you. The first general manager of what was called The Associated Press was one Dr. Jones. He was an authority upon telegraphs—at least he thought he was. He wrote a book on the subject. It may be found in one or two of the public libraries. In it he declared himself in no uncertain terms respecting the absurd proposal to connect America with Europe by a submarine cable. "It cannot be done," said he; "experience has shown that a relay every forty miles is necessary to carry the electric current along. And how can you have such relays in the bed of the ocean?"

"There is only one way to reach Europe by telegraphy," he continued; "that is to build a line up through British Columbia and Alaska to the Bering Sea, and thence across Siberia to Moscow, and Paris, and London." And the telegraph company adopted this view. They sent two expeditions, one to British Columbia and the other to Siberia. They were putting up poles and stringing wires, when one day a message announcing the successful operation of Mr. Cyrus Field's cable was received. In an hour their work ceased, and some rotted poles up near the Alaskan border, at a place still known as Telegraph Hill, remain as a monument of their error.

One of those who went to Siberia was Mr. George Kennan, a telegraph operator and editor of The Associated Press, who there learned of the horrors of the prison mines, and who, in book and lecture, has since done so much to enlighten the world upon the subject.

As I have said, Topliff's work was taken up by others. Among and chief of these was a Mr. Craig, who proved an ag-

gressive, enterprising, and altogether remarkable man. As an independent news-gatherer, he contested the field with the combination of New York City papers, perfected about 1850, and enjoying the aid of the newly-invented Morse telegraph lines. This combination was popularly named The New York Associated Press, although it never was incorporated and therefore never had a legal title. Its general manager was the Dr. Jones of whom I have spoken. Craig won in the struggle and displaced Jones, and for several years achieved distinction in the business.

But this New York Associated Press carried in its organization and methods the seeds of its own destruction. It was really a partnership of seven newspapers. They gathered the news of the world and sold it to the newspapers of the country published outside of the metropolis. It was inevitable that, sooner or later, there should be trouble. And so there was. Out in the West there was organized the Western Associated Press, which contracted with the New York Associated Press for an exchange of service. This went on for some years, until it grew very unsatisfactory to the Westerners. The New York organization gathered such news as it pleased, and the Western papers had no voice in the business. In 1882, on my motion, I then being a member and director of the Western Associated Press, we broke with the New York people and set out for ourselves. There was a sharp but very short-lived contest. Then there was a Compromise combination. And for ten years this lasted. Meanwhile I went out of journalism. All the while I was convinced that the method of operation of these associations was fundamentally wrong. They were all conducted as money-making ventures; that is, a limited number of newspaper proprietors organized into an association, gathered news, and sold it at a profit to other newspapers or organizations of newspaper owners. There were a dozen or more of these associations. The chief one was the New York Associated Press. As I have said, it was a partnership of seven New York newspaper proprietors. This concern gathered primarily the foreign and Washington news, as well as information respecting the happenings of New York City. It exchanged its budget of news with the smaller associations scattered over the country, exacting a differential annual payment to represent the larger value of the news provided by the NewYorkers than that of the news of the smaller

companies. There were many objections to this system. It was not always fair from a merely financial point of view. The New Yorkers held the whip-handle and naturally were led into using it to exact larger bonuses than were just. Then, too, they determined the character of the news they gathered with little care for the needs or wishes of the papers in the interior of the country, which were dependent upon them. And they had an alliance with the telegraph company which gave them reduced rates and exclusive privileges, making competition practically impossible. In such circumstances they were easily able to poison the channels of news, although I think it right to say that there is little evidence that they ever did so in any considerable degree.

Withal, it was fortunate that their ways brought disaster to their association. As I have said, the quarrel with the Western Associated Press, which operated between the Allegheny and Rocky Mountains, was patched up in 1882, and there was comparative peace for ten years. In this decade, however, new telegraph companies sprang into existence and made possible competing news associations. So in 1892 the dominance of the New York people was broken, and its work was handed over to what was then called the United Press, an institution having a small number of shareholders and practically a close corporation. Indeed, within a short time it was ruled by three men, only one of whom was a practical journalist. Out of this there was widespread discontent, but also widespread confusion. My old-time friends and former associates in the Western Associated Press were particularly disturbed. They met in general convention in Chicago, and appointed a committee to wait upon me and ask me to accept the post of general manager of the organization which they had in mind. This was the beginning in purpose as well as in fact of what seems to me to have been, in form at least, an ideal news-gathering association.

We believed that, with a self-governing people, it was all-important that they should be well-informed: informed truthfully and honestly respecting the affairs of the day. There should be no chance that they should be misled, if it were possible to achieve such an end. There was a public duty, of a very high character, involved in the matter. Not alone, if you please, that the market reports for the investor, or the merchant, or the farmer should be accurate, but—deeper and more important—

in our political life, where the very business of government was at stake and vital, the truth, impartially, without bias or alien purpose, should be furnished for the guidance of the electorate. Obviously this was not to be secured from an agency operated by a few men, owing no responsibility to any one.

Then ensued a prolonged consideration of the subject, and it was agreed, as a result, that the best thing to do was to establish a nation-wide association, of a coöperative character, with no capital, no profits, no dividends—including as members papers of every conceivable political, social, and religious bent, and subject to the control and censorship of these varied interests. This, it was believed, would give the best guaranty of unbiased, nonpartisan, and wholly impartial reports of current events.

There was a four years' contest to make a success of such an institution. It was a case of private interest against public service. A large amount of money was expended by men who were wedded to the idea of a pure fountain of news service. And in the end their efforts were crowned with victory. This, my friends, is the history of the founding of The Associated Press of to-day.

And now what is it? And how does it operate? First, there are something like nine hundred members, each owning a daily newspaper and each having a vote in determining the management. These nine hundred members represent every angle of every fad or ism outside the walls of Bedlam. And not only each member, but every employee of every member—nay, more, every reader of every one of these nine hundred daily papers sits in hourly judgment on the service which The Associated Press is rendering. This criticism was expected by those of us who founded the institution, and it is not at all to be deplored. It is the thing which safeguards an honest and truthful service of news to you. There are competing organizations, and their rivalry tends to celerity in gathering and presenting the news. I do not undervalue this feature of our work, yet I regard its reputation for truthfulness and strict impartiality as the best asset of The Associated Press. It is far less important that you get prompt news than that you get true news. Every one familiar with our work knows that it is utterly impossible for any one in the service, from the general manager to the least important agent at the most remote point, to send an untruthful dispatch

and escape detection. You may write a biased or inaccurate statement for a single newspaper and "get away with it," but you cannot do it with the argus-eyed millions who read the dispatches of The Associated Press. The very magnitude of its work tends to make truthfulness and impartiality imperative. I am not laying claim to any great virtue. I am saying that, under its system of operation and in view of the millions of critics passing upon its work, it is automatically truthful and fair. As one evidence of this, it is just to say that in the twenty-three years of the present management of the news service, although we have delivered untold millions of words of news every month, we have never paid a dollar of damages in an action for libel, nor have we compromised any case.

If we made an error, we have, and always will, correct it in the most straightforward and ample fashion. We have no squeamishness about this. I am convinced that there is no tyranny greater than that of the printed word, and that a newspaper loses nothing, but gains greatly, by an honest confession of error. It is not easy to establish a reputation for infallibility; it is very easy to secure a reputation for integrity, if it is deserved. And this is the thing that is of real value.

But, after all, let us return to our "muttons." For, I dare say, you are asking, how does all this explain how the world's news is gathered and furnished you in a newspaper issued at one cent a copy? First, as to the foreign news, which is, of course, the most difficult to obtain and the most expensive. Well, in normal times there are four great agencies which, with many smaller and tributary agencies, are covering the whole world. These four agencies are the Reuter Telegram Company, Ltd., of London, which assumes responsibility for the news of the great British Empire, including the home land, every colony except Canada, and the suzerain or allied countries, as Egypt, Turkey, and even China and Japan; and the Agence Havas, of Paris, taking care of the Latin countries, France, Italy, Spain, Portugal, Belgium, Switzerland, and South America, as well as Northern Africa; and the Wolff Agency of Berlin, reporting the happenings in the Teutonic, Scandinavian, and Slav nations. These three organizations are allied with The Associated Press in an exclusive exchange arrangement. Subordinate to these

agencies is a smaller one in almost every nation, having like exchange agreements with the larger companies.

Thus it happens that there is not a place of moment in the habitable globe that is not provided for. Moreover, there is scarcely a reporter on any paper in the world who does not, in a sense, become a representative of all these four agencies. Let me explain how this comes about. Not only have we these alliances, but in every important capital of every country, and in a great many of the other larger cities abroad, we have our own men, trained by long experience in our offices in this country. This we do because, first, we are anxious to view every country with American eyes; and, second, because a number of the agencies of which I have spoken are under the influence of their governments and, therefore, not always trustworthy. We rely upon them for a certain class of news, as, for instance, accidents by flood and field, where there is no reason for any misrepresentation on their part. But where it is a question which may involve national pride or interest, or where there is a possibility of partisanship or untruthfulness, we trust our own men.

Now, assume that a fire has broken out in Benares, the sacred city of the Hindus, on the banks of the Ganges, and a hundred or a thousand people have lost their lives. Not far away, at Allahabad or at Calcutta, is a daily paper, having a correspondent at Benares, who reports the disaster fully. Some one on this paper sends the story, or so much of it as is of general rather than of local interest, to the agent of the Reuter Company at Calcutta, Bombay, or Madras; and thence it is cabled to London and Hong Kong, and Sydney and Tokyo. At each of these places there are Associated Press men, one of whom picks it up and forwards it to New York.

If the thing happens in Zanzibar, the story goes either to Cairo or Cape Town, and by the same process finds its way to London, and on to us in this country. Thus the wide world is combed for news, and in an incredibly short time is delivered and printed everywhere. When Pope Leo XIII died in Rome the fact was announced by an Associated Press telegram in the columns of a San Francisco paper in nine minutes from the instant when he breathed his last. And this message was repeated back to London, Paris, and Rome, and gave those cities the first information of the event. When Port Arthur was taken

by the Japanese in the war of 1896 it came to us in New York in fifty minutes, although it passed through twenty-seven relay offices. Few of the operators transmitting it knew what the dispatch meant. But they understood the Latin letters, and sent it on from station to station, letter by letter.

When Peary came back from his great discovery in the Arctic Sea he reached Winter Harbor, on the coast of Labrador, and from there sent me a wireless message that he had nailed the Stars and Stripes to the North Pole. This went to Sydney, on Cape Breton Island, and was forwarded thence by cable and telegraph to New York.

For its domestic service other methods are adopted. The territory covered includes the United States proper, Alaska, the Hawaiian Islands, the Philippines, the islands of the Caribbean Sea, Mexico, the Central American States, and, by an exchange arrangement with the Canadian Press, Limited, the British possessions on this continent.

The organization is, as you have been told, coöperative in its character. As a condition of membership, each one belonging agrees to furnish to his fellow-members, either directly or through the association, and to them exclusively, the news of his vicinage, as gathered by him for his own paper. This constitutes the large fountain from which our American news supply is drawn. But, as in the case of the foreign official agencies, if there be danger that an individual member is biased, or if the matter be one of high importance we use our own trained and salaried staff men to do the reporting. For this purpose, as well as for administrative work, we have a bureau in every leading city.

For the collection and interchange of this information we lease from the various telephone and telegraph companies, and operate with our own employees, something like fifty thousand miles of wires, stretching out in every direction through the country and touching every important centre. To reach smaller cities, the telephone is employed. Everywhere in every land, and every moment of every day, there is ceaseless vigil for news.

I am frequently asked what it costs thus to collect the news of the world. And I cannot answer. Our annual budget is between three and four million dollars. But this makes no account of the work done by the individual papers all over the world in reporting the matters and handing the news over to the agencies.

Neither can I estimate the number of men and women engaged in this fashion. It is easy to measure the cost of certain specific events; as, for instance, we expended twenty-eight thousand dollars to report the Martinique disaster. And the Russo-Japanese war cost us over three hundred thousand dollars.

Such, my friends, is an outline of our activities in what we call normal times. But these are not normal times. When the great European war broke on us, eighteen months ago, all of the processes of civilization seemed to go down in an hour. And we suffered in common with others. Our international relations for the exchange of news were instantly dislocated. We had been able to impress the governments abroad with the value of an impartial and unpurchasable news service, as opposed to the venal type of journalism, which was too common on the European continent. And in our behalf they had abolished their censorships. They had accorded us rules assuring us great rapidity in the transmission of our messages over their government telegraph lines. They had opened the doors of their chancelleries to our correspondents, and told them freely the news as it developed.

All these advantages ceased. The German news agency was prohibited from holding any intercourse with the English, French, or Russian organizations. Simultaneously, like commerce was interdicted in the other countries. The virtues of impartial news-gathering at once ceased to be quoted at par. Everywhere, in all of the warring lands, the Biblical rule that " He that is not with me is against me " became the controlling view. Government telegrams were obviously very important, and there was no time to consider anywhere any of the promised speed in sending our dispatches. Finally, censorships were imposed. This was quite proper in principle. Censorships are always necessary in time of war. But it is desirable, from every point of view, that they be intelligent.

I am sorry to say that, for crass stupidity, some of the European censoring has never been equalled unless it was in the days of our Civil War. In 1862, Secretary Stanton instituted at Washington a military control of news telegrams which will ever remain a monument of imbecile autocracy. Those in charge of the business were wholly without qualifications for the work, and their antics were both annoying and ludicrous. For instance, information printed in the Washington papers without objection

could not be sent to Boston or Chicago, but was frequently copied by the Boston and Chicago papers after the Washington papers had been smuggled through the Confederate lines to Richmond, the news printed in the Richmond papers, and these, in turn, smuggled back through the Federal lines to the North.

Well, like doltish management has characterized much of the censorship abroad and has increased our difficulties. Mark you, we fully recognize the propriety and need of a military censorship and have no thought of objecting to it. But when the business is put in the hands of people who, alike because of their censurable habits or their lack of ordinary elementary education, are often in no condition to exercise any discriminating judgment, we do protest.

Nevertheless, I feel that we have fared pretty well in the business of reporting this war. We have made distinct progress in teaching the belligerents that we hold no brief for any one of them, and, while each would much rather have us plead his cause, they are coming to see why we cannot and ought not to do so. And our men, I am glad to say, are everywhere respected and accorded as large privileges as, perhaps, in the light of the tension of the hour, could be reasonably asked.

During this war we have more men and more offices in Europe than any other news-gathering organization ever had, and are expending even greater sums. Last week, for example, we received the speech in the Reichstag of Chancellor von Bethmann-Hollweg and the German Baralong Note not only by wireless but also by the costly cable route through Holland and England to New York. In tolls alone the cost to The Associated Press of such matter was over one dollar a word—yet this all goes to you in your penny paper.

When the Austro-Hungary Government prepared a reply to the American note on the sinking of the *Ancona* the reply was relayed by Associated Press men from Vienna to Berlin, from Berlin to The Hague, from The Hague to London, and from London to New York, and delivered, in spite of the censorships, to virtually every newspaper reader in the United States thirty-six hours before it was decoded in the State Department at Washington.

Yesterday's *London Times* complained that the version of Germany's Baralong correspondence published in London was in-

complete, although neutral countries received the full German report, and added:

"Some idea of the importance attached by the German Government to the correspondence may be gleaned from the fact that the whole dispatch was sent direct from Berlin by wireless to New York, where it was transmitted exact to 1000 leading American newspapers through The Associated Press."

There is much misunderstanding in the public mind respecting the limitations which we believe, with distinct propriety, have been imposed upon The Associated Press.

Also, many people are unable to distinguish between Associated Press despatches and special telegrams for which we have no responsibility, and yet for which we frequently receive undeserved blame.

There are certain things which it should do, and others which it must not do. It should report the important events of the day as fairly and truthfully and impartially as is possible for human beings to do. It may not go further. It must give both sides of a question fair treatment. But it must not hint that either side is right or wrong. It may be claimed that this sort of negative work has no value; that The Associated Press sees a great wrong and makes no sign of disapproval. It sees a movement for the betterment of mankind which is of the highest moment, and does not lend a hand to help the thing along. Let us see. There is an underlying belief that the American people are capable of self-government. If so, they must needs be able to form a judgment. And we conceive it to be of very great importance that the people be given the facts free from the slightest bias, leaving to them the business of forming their own judgment. Let us see what any other method of dealing with the news of the day must mean. If a news agency is to present somebody's view of the right or wrong of the world's happenings, whose view is it to be? And what assurance are we to have that the somebody's view is the right view? And if it is the wrong view, what then?

One final word: The Associated Press, reaching as it does with its dispatches the great body of the American people, has very large responsibility. And we believe the business of news-gathering, when properly done, has a distinct moral value. Notwithstanding all I have said about the impartiality of the association, and nowithstanding the fact that it takes no part for

either side in any controversy, it nevertheless has an enormous influence upon American life. Adopting the terminology of our medical friends, "We cure diseases upon the body-politic by the aseptic and not by the antiseptic method."

Given a correct environment, we leave nature to do the rest. If, with the truth before them, the people choose to go wrong, that is their affair, not ours. We furnish an atmosphere of truth which necessarily leads to purifying the cesspool. We furnish the light which flames out into the dark places and makes impossible "treason, stratagem, and spoils."

We do not hunt out scandals or gruesome tales for the sole purpose of pandering to vitiated desires, but bend our energies toward writing the real and abiding history of the day. The association is a voluntary union of a number of gentlemen for the employment of a certain staff of news reporters to serve them jointly. For its work it derives no advantage from the government, from any state or municipality, from any corporation, or from any person. I have no thought of saying that it is perfect. The frailties of human nature attach to it. But of this I am certain: If, in its form of organization or its method of operation, it is in violation of any law, divine or human, it is the very last institution in this country to seek to avoid its responsibility. If any one can devise or suggest a better way to do the work it is seeking to do, it will be glad to adopt it, or to permit some one else to put it in operation. The thing it is striving for is a truthful, unbiased report of the world's happenings, under forms that are legal, and not only conformable to statutes, but ethical in the highest degree.

The Action on Boiling Acetic, Propionic, and Butyric Acids on Aluminum. R. SELIGMAN and P. WILLIAMS. (*Journal of the Society of Chemical Industry,* vol. xxxv, No. 2, January 31, 1916.)—The work described in this paper forms part of an extended inquiry which has been undertaken with the object of clearing up some of the anomalies to be found in literature dealing with the action of acids upon aluminum. The present contribution relates only to one small section of the work; namely, the action of certain hot concentrated, volatile fatty acids.

Aluminum stills have been used for a number of years for the distillation of acetic acid, and it has been found that, whereas some parts of the apparatus withstand the action of the acid in a very

satisfactory manner, other parts are subject to rapid corrosion. It was considered, at the outset of the experiments made to determine the conditions governing the rate of attack, that the presence or absence of air might be the main factor, but this assumption was found to be erroneous, although there was some evidence that, in the absence of oxygen, dissolution is more uniform than when oxygen is present. On the other hand, the question of concentration was found to be all-important, quite exceptionally narrow limits defining the strength of acid which causes rapid dissolution of the metal. As was to be expected, the rate of dissolution falls as the strength of the acid increases, so that a 99 per cent. acid has only about one-tenth the action upon aluminum of a 90 per cent. acid. But the astonishing fact was brought to light that the removal of the last 0.05 per cent. of water is sufficient to raise the rate of dissolution a hundred-fold, while, conversely, the addition of 0.05 per cent. of water to a corrosive acid suffices to stop the action.

Experiments on butyric acid showed that its action on aluminum was similar in all respects to that of dehydrated acetic acid, rapid dissolution of the metal taking place. This experience led to a similar series of experiments with propionic acid. In this case also perfect analogy between the acids was established. It has not been possible to experiment with dehydrated formic acid, but the action of boiling 77 per cent. acid has been briefly examined. This acid attacks aluminum very rapidly, a crystalline salt being formed. Finally experiments were made with a mixture of higher fatty acids, containing 55 per cent. palmitic acid, 40 per cent. stearic acid, and 5 per cent. oleic acid. At temperatures up to 300° C., aluminum has been presumed to be quite unaffected by these acids, but occasionally, in the course of industrial work, a case of pitting has come to light which it is quite impossible to explain.

"Safety-first" Exhibit, Washington, D. C., February 21-26, 1916.—There was held in Washington, during the week of February 21–26 inclusive, a "safety-first" exhibit in which all of the government departments took an active part. This exhibit took on a national aspect, as manufacturers and operators from all over the country were invited to be present, in order that they might see what the Government of the United States had done in "safety-first" work.

Secretary of the Interior Lane had sent a letter to the governor of each state inviting him to send a delegate, and asking that the Chief Mine Inspector, a representative of the Industrial Commission, or of other agencies engaged in compiling statistics relating to the various mineral industries, also attend this exhibition.

INVESTIGATION OF MAGNETIC LAWS FOR STEEL AND OTHER MATERIALS.*

BY

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In coming before you this evening I appreciate the fact that I have the honor of addressing an old and established scientific society, and I have taken an old and established scientific subject, "Magnetism."

Magnetism, while quite different from electricity, is so closely associated with the latter in electric machines and in science in general that we now consider magnetics as a branch of electrical engineering, and as such its study is probably the oldest of the component parts which made the present science. It is therefore gratifying that upon this occasion I find present representatives of the American Institute of Electrical Engineers.

From the length of time magnetic phenomena have been observed, we might think that the subject is so old, and the work done by distinguished experts so thorough, that there is little left to be accomplished. As a matter of fact, much has been done and learned since the peculiar properties of the lodestone were first observed, yet to-day the subject is by no means thoroughly understood. Our formulæ are mostly empirical, and the variations in magnetic material under different, and even under apparently the same, conditions show so many unaccountable variations from what we consider as correct, that a book on "What we Cannot Account for in Magnetic Behavior" would be easy to write.

That the subject is a live one is witnessed by the number of articles which have been presented before this and other learned societies.

I will not attempt to give you a *résumé* or bibliography of magnetic research in general, but will present to you results of some of our own investigations made during the past two years.

The work has been done with two purposes in view:

Primarily to study magnetic phenomena with a hope of aiding

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, December 2, 1915.

the discovery of their true nature, and secondarily to study the magnetic properties of materials to assist in the economical design of apparatus.

Probably the two most valuable magnetic laws which we have to-day are the reluctivity equation of Dr. Kennelly, which is a modified form of Fröhlich's equation, and the 1.6 law of Dr. Steinmetz. These two laws give us our best method of attack on magnetic problems. A considerable number of test results has been obtained and much literature written attempting to show apparent inconsistencies in these laws, especially referring to the latter. The fundamental idea of the present investigation was, therefore, to determine the accuracy and cause of these apparent deviations of observed test values from the reluctivity equation of Kennelly and the hysteresis equation of Steinmetz. About three years ago Dr. Steinmetz suggested that these apparent deviations might be due to the fact that the materials tested were not homogeneous. As it was found that the deviations were most noticeable in silicon steel, and as the hysteresis losses in this material are especially interesting from the standpoint of electrical manufacturers, properties of this steel were closely examined. On the theory that heterogeneous materials cause the deviations from magnetic laws, it became necessary to separately determine the properties of steel, free from scale, and the properties of the scale itself. It became also desirable to further investigate the theory by artificially reproducing the characteristics of a heterogeneous material by testing a sample which consisted of two component metals; one of the samples selected was a ring which was practically pure iron, and the other cobalt. The two rings were fastened together and tested as a single sample, after which the properties of each ring were determined separately.

During the process of the investigation we also studied the second hysteresis law of Dr. Steinmetz, or the hysteresis losses in unsymmetrical loops; that is, where the mean introduction of the loop occurs at a density other than zero.

The present paper is divided into the following divisions:

I. Review of the reluctivity law of Kennelly.

II. The hysteresis law of Steinmetz.

III. The theory of the changes in flux distribution in heterogeneous material to account for apparent deviations in the above laws.

IV. Properties of scale from silicon steel.
V. Application of scale data to show distribution of flux and losses in sheet steel as affected by the presence of steel.
VI. Tests of iron and cobalt separately and together to reproduce effects of steel with scale.
VII. Applications of data in calculating losses.
VIII. Brief *résumé* of investigation to determine losses in unsymmetrical loops.
IX. Appendix: Properties of scale from silicon steel of general interest and value, but not pertinent to the present investigation.

I. The Reluctivity Law of Kennelly.

The reluctivity law of Dr. Kennelly as announced is: that for magnetic materials the reluctivity (which is the reciprocal of the permeability), when plotted against the magnetizing force H, gives a curve which, from minimum reluctivity upwards, approximates a straight line over a wide range of values.[1] However, as pointed out by Dr. Kennelly, we find in most cases that the curve is not a straight line, but rather two straight lines joined by a sharp, decided bend. From plotting and examining several hundred curves for many varieties of steel, for nickel, monel metal, "binel" metal, and other metals, we have found that for a given material the bend apparently occurs at a definite value of magnetizing force H, irrespective of the flux density B. Closer examination indicated that above this value of H there are no bends, but below this value there are often evidences of several bends. In any curve there is but one salient deflection, the others being much less pronounced. A variety of these curves are shown in Dr. Kennelly's article.

A curve of the test results of a sample of high silicon steel is shown on Fig. 1, which may be taken as a typical curve. Other curves for silicon steel may be found in another paper.[2]

The reluctivity, ρ, is given by the equation $\rho = \alpha + \sigma H$, wherein:

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[1] Magnetic Reluctance," A. E. Kennelly, *Trans. A. I. E. E.*, vol. viii, 1891, pp. 485–517.

[2] "Reluctivity of Silicon Steel," J. D. Ball, *Gen. Elec. Review*, vol. xvi, 1913, pp. 750–754.

α is a constant representing the distance from the X axis to the intercept of $\rho - H$ curve if continued along the straight line.

σ is a constant representing the slope of the line. We may consider that α represents the magnetic hardness of the material, as the harder the metal (magnetically) the greater the value of α. The constant σ has been named the coefficient of magnetic saturation because its reciprocal gives the value of absolute saturation of metallic induction.[3] Tests made at very high magnetizations by use of the isthmus method,[4] check ultimate saturation values as found by $\frac{1}{\rho}$ of the $\rho - H$ curve taken at moderate field strengths.

As $\rho = \frac{H}{B}$ and also $\rho = \alpha + \sigma H$, then the induction.

$$B = \frac{H}{\alpha + \sigma H} \quad [5]$$

Examining the curve Fig. 1, we note that from maximum permeability to about $H = 80$ the flux apparently enters a material having an apparent ultimate saturation of $B = 17{,}000$; then later the curve shows a changed condition, as if the flux passed through material whose apparent ultimate saturation is in the neighborhood of $B = 20{,}000$, and whose α shows a harder material. This indicates that the two lines apparently may represent two magnetic materials, one of which takes most of the flux first, and the other carries the additional flux after the first is presumably saturated, or the permeability of the second part begins to increase much more rapidly than in the first.

Before going into detail further concerning the theory of

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[3] "On the Law of Hysteresis," C. P. Steinmetz, *Trans. A. I. E. E.*, vol. ix, 1892, p. 625 *et seq.*

[4] See "Electrical Properties of Iron and Its Alloys in Intense Fields," Sir Robert Hadfield and Professor B. Hopkinson, *Journ. I. E. E.*, vol. lvi, 1911, pp. 235–306, etc.

[5] There are reasons why the true metallic density $4\pi I$, which is $B - H$, should be used for extrapolation and other applications of this law; this has also been written B_o. In this case the metallic reluctivity $\frac{H}{4\pi I}$ would be represented by $\rho_o = \alpha_o + \sigma_o H$ and

$$B = \frac{H}{\alpha_o + \sigma_o H} + H$$

This is discussed in a previous paper, "Some Notes on Magnetization Curves," *Gen. Elec. Rev.*, vol. xviii, 1915, pp. 331–35. For the ranges involved in the present discussion, B_o is so nearly identical with B that the difference is negligible and is not taken into account.

changes in flux paths it is desirable to briefly review the hysteresis law of Steinmetz.

II. The Hysteresis Law of Steinmetz.

In the early part of 1892, Dr. Steinmetz presented the well-known classic paper on "The Law of Hysteresis" and gave us the law $h = \eta B^{1.6}$[6] wherein:

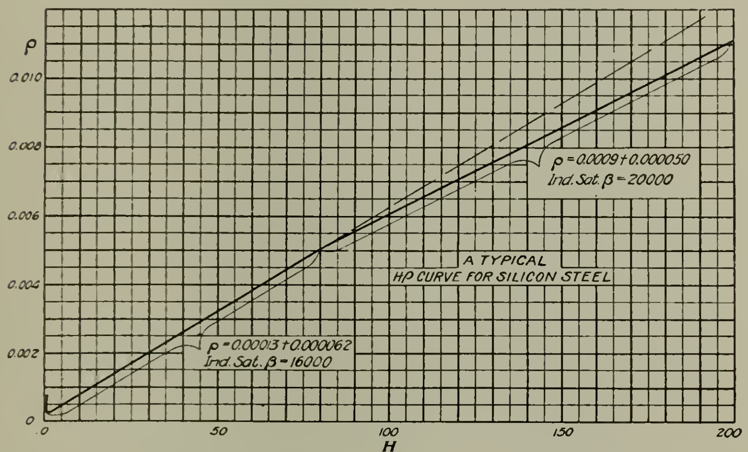
h = the hysteresis loss per cycle in ergs per cm.^{3}

B = the maximum induction.

η = a numerical coefficient depending upon the material.

The great value of the discovery has been recognized and re-

FIG. 1.



quires no comment here. Along in 1910–11, shortly after the German specifications were adopted that the standard test of steel should be made at B = 15.000 as well as B = 10,000,[7] a number of experimenters made calculations which gave for the higher ranges of inductions values of the exponent on the order of 3. Some of these values have been published. The calculations were in error, due to certain misconception of taking the percentual slope of the curve log h – log B as the exponent where the curve was not a

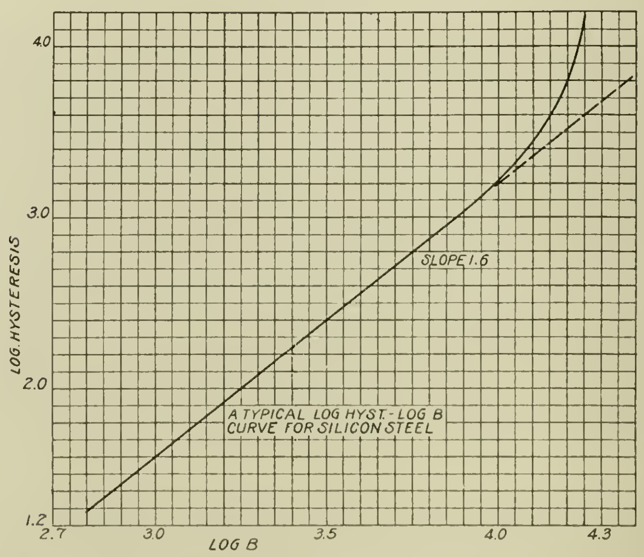
[6] "On the Law of Hysteresis," C. P. Steinmetz, *Trans. A. I. E. E.*, vol. ix, 1892, pp. 3–51; also vol. ix, 1892, pp. 621–729; vol. xi, 1894, pp. 570–608.

[7] For present standard see V. D. E. Rule's "Normalien für die prüfung von Eisenblech."

straight line or the original $h - B$ curve was not exactly parabolic. Examination of data, however, does show an apparent increase of the exponent at the higher inductions, the exponent increasing to, say, 1.63 at $B = 15{,}000$

Tests on many samples of 2½ per cent. silicon steel and 3½ per cent. silicon steel as commercially used show losses at $B = 15{,}000$ to be apparently 30 per cent. higher than would be given by the loss at $B = 10{,}000$ and strict application of the law. In other words, the ratio of losses at $B = 15{,}000$ and $B = 10{,}000$ is about 2.5 to 3.5 instead of the value of $\left(\frac{15{,}000}{10{,}000}\right)^{1.6} = 1.91$.

FIG. 2.

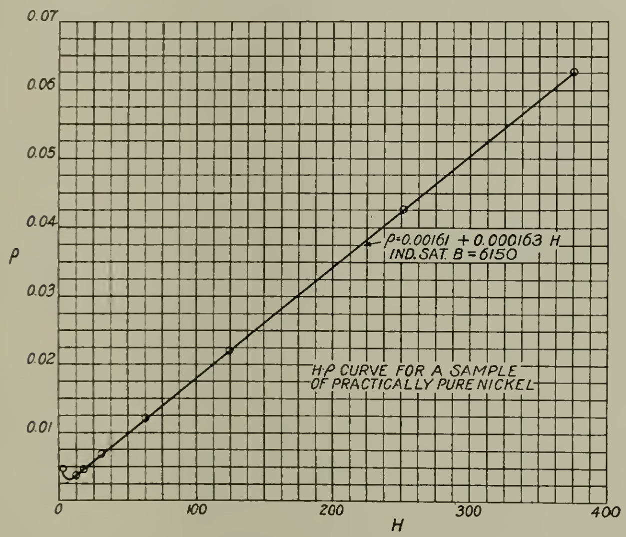


Plotting a typical log h – log B, we find results as given on Fig. 2. The solid curve represents the observed data, and the dotted continuation of the straight line shows what results might be expected if the law was absolutely correct. If we assume that the 1.6 law holds, we see that to about $B = 10{,}000$ the flux enters a material of certain characteristics, but beyond that point the more appreciable amount of the flux is going through some magnetically harder material characterized by greater reluctivity and a higher value of η.

III. The Theory of Changes in Flux Distribution to Account for Apparent Deviations in Magnetic Laws.

As pointed out, the bend of the reluctivity curve indicates a non-homogeneous material or a material whose component parts may be divided into two magnetic materials, whose characteristics are different, and in consequence carry different percentages of flux as the magnetizing forces are varied. In such a case the softer material would carry a correspondingly greater amount of flux until approaching saturation reduces the permeability, after which the additional flux is forced into the harder material, whose

FIG. 3.



permeability is then correspondingly higher than before. The percentage of flux in the harder material will then increase very rapidly, due to the fact that the softer material, is becoming saturated, and can carry little additional flux. At varying values of magnetizing force the percentage of flux in the two materials constantly varies, due to the fact that the rate of change of their respective permeabilities is constantly varying.

It would be expected that if pure or homogeneous materials were taken the reluctivity curves would be straight. Tests have been obtained showing this to be true, as, for example, Fig. 3 gives an $H - \rho$ curve for a sample of nearly pure nickel. The chemi-

cal analysis showed: Ni 98.91, Cu 0.33, Fe 0.31, Mn 0.21, Si 0.07, Co 0.15. Here we see no evidences of bend, but a straight line from approximately $H=9$ ($B=3000$) to $H=377$ ($B=6350$), the limit of the test. A study of this curve would indicate that in this case the flux is passing through a material whose magnetic characteristics are constant throughout the range of the test.

Referring to the hysteresis law, the deviation from the straight line in the $\log h - \log B$ curve also indicates a heterogeneous material. The most prominent deviations from the reluctivity and hysteresis laws do not occur at the same value of the magnetizing forces, nor would it be expected. The bend of the reluctivity curve would be predicted at a value of H where one material approaches the saturation value. The rapid increase of the hysteresis loss would occur at a point where the permeability of the harder material (which is characterized by the greater value of η) increases at a more rapid rate than the permeability of the softer. This change would be expected at about the value of H, where the softer material reaches maximum permeability, although not necessarily at this point. Beyond this, additional H gives less relative increase of induction, while the relative induction in the second material continues to increase until its permeability is a maximum, which occurs at a much higher value of H.

We know that our sheet steel as commercially used is by no means magnetically homogeneous. The fact that it is especially prominent is that about 10 per cent. of the ordinary sheet consists of scale, which scale is naturally less magnetic than iron and at the same induction would have much greater hysteresis loss. In order to further demonstrate this theory, it would be interesting to have a purely theoretical case, where a heterogeneous material forms two or more magnetic paths in multiple, and note the behavior of the combined curves when calculated by assuming the component part thereof to be subjected to the same values of excitation. Unfortunately this is not practical, as it would be necessary to have values of the normal induction curve below maximum permeability for at least one of the components, and we have not as yet been successful in obtaining an equation of the magnetization curve below maximum permeability. A curve representing materials might be drawn at random, but results derived therefrom would necessarily be neither accurate nor convincing. We

are therefore forced to investigate our theory with actual data, which, after all, is the correct method of investigating empirical formulæ.

As steel and scale are the salient components of our sheet steel, it becomes desirable to determine the characteristics of scale from silicon steel when removed from the steel itself. We will therefore leave the general investigation of magnetic laws for the time being, to give results of tests on steel scale.

IV. Properties of Scale from Silicon Steel.

It is a well-known fact that when steel is heated the exposed surfaces combine chemically with surrounding gases and form a thin scale. Such formations appear when steel is taken from rolling mills, and the thickness thereof is usually greater after materials are subjected to annealing processes. In thin sheets the scale on both sides is usually sufficient to amount to about 10 per cent. of the total cross-section. In silicon steels this scale is usually in flakes, and sometimes may be easily removed from the sheets. Often large sections may be peeled off, in which manner samples were obtained for this investigation. The samples tested were built of large flakes accumulated from time to time, and therefore are more representative than if a whole sample was taken from one heat or lot only.

The study of steel scales and a knowledge of their properties were required primarily for assistance in determining magnetic laws for materials wherein scale exists, thus rendering test specimens non-homogeneous. Also, it is of interest to be able to determine effect of scale in electrical machines wherein the scale occupies a portion of a section of a magnetic core.

Tests were made on a scale from steel containing 3.5 to 4.3 per cent. silicon. One sample of scale was obtained from steel annealed in the ordinary way, which is herein referred to as "mill-annealed." The second variety was obtained from steel annealed at high temperature in a vacuum furnace, which will be herein designated as "vacuum-annealed scale."

For the present discussion the mill-annealed scale is used, but, as the properties of scale from vacuum-annealed steel are of general value, results of these tests are given in the Appendix.

SCALE FROM MILL-ANNEALED STEEL.

Physical Appearance and Size of Sample.

The scale from mill-annealed silicon steel is dark gray in color, is somewhat pitted, and is fairly rough. The material is reasonably tough, but is, of course, much more brittle than the steel itself. The sample tested was made up of ring punchings 8.89 cm. (3.5 inches) outer diameter, 6.86 cm. (2.9 inches) inner diameter, and weighed 85 grammes (0.187 pound). The average thickness of the sheets was 0.0064 cm. (0.0025 inch). The scale was obtained from sheets 0.035 cm. (0.014 inch) thick.

Chemical Analysis.

The first analysis of this material gave the following results:

Si	7.02
S	0.047
Mn	0.08
C	0.054

Analysis for oxygen gave 1.2 per cent., which was rather surprising, as scale is usually considered as a magnetic oxide, which would, of course, have a larger percentage of oxygen.

A later, and probably more reliable, analysis gave:

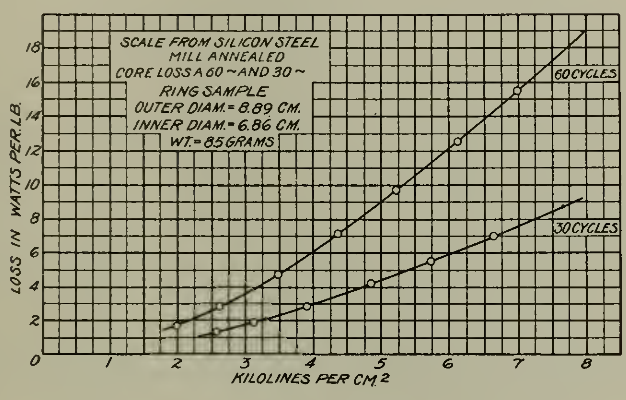
Si	5.28	5.52
S	0.047	0.046
P	0.042	0.041
Mn	0.310	0.300
C	0.307	0.300
Total Fe	75.84	76.21
Total per cent.	81.826	82.417

As before stated, the analysis for oxygen gave only 1.2 per cent., but it is well known that such determinations are often not reliable. In all probability, the 18 per cent. missing in the above tabulations is oxygen. We know that all of the silicon and some of the iron exist as oxides. Considering the silicon to appear as SiO_2, and assuming the iron in the oxide form to be in Fe_3O_4, calculated values may be derived from the analysis of the first specimen tabulated above, giving the following possible chemical content:

Si O_2	11.23
S	0.047
P	0.042
Mn	0.310
C	0.307
Fe (free)	43.764
Fe_3O_4	44.3
Total	100.00

The above table of possible values is undoubtedly not entirely correct, as some of the silicon may be in the metallic form, and the iron doubtless appears not only as metallic iron and Fe_3O_4, but there may also be other iron oxides present, making the chemical contents of a more complicated nature.

FIG. 4.



Resistivity.

A sample of mill-annealed scale 0.0050 cm. (0.002 inch) thick was secured for resistivity measurements. The average of the measurements gave a resistivity of 126.6 microhms per cm.^{3} at 25° C. The individual values varied from 107 to 157. A test on 0.0064 cm. (0.0025 inch) scale gave 140 microhms per cm.^{3}, which lies within the results obtained on the thicker scale. Resistivity of silicon sheet steel, such as produced this scale, is usually between 55 and 60 microhms. Ordinary sheet steel gives about 12, and cast iron 80 to 85 microhms.

Specific Gravity.

The specific gravity determination of this scale gave 5.54. The gravity of the steel itself is approximately 7.5.

Core Loss.

Core loss tests were made on the ring samples, at 60 cycles and 30 cycles, at inductions of from $B = 2000$ to $B = 7500$. The results of tests are shown on curve, Fig. 4. Data derived from the curves are tabulated with the discussion of the hysteresis loss.

Hysteresis Loss.

The hysteresis loss at various densities was first determined from the core loss tests by using the separation method. This was done by taking values from the core loss curves at 60 cycles and 30 cycles and obtaining the loss per cycle, as shown in Table I.

TABLE I.

Losses in Scale from Silicon Steel

(Losses in watts per pound.)

B	Total losses 60 cycles	Total losses 30 cycles	Loss per cycle 60 cycles	Loss per cycle 30 cycles	Loss per cycle at 60 cycles Hysteresis	Loss per cycle at 60 cycles Eddy
7500	17.4	8.5	0.29	0.283	0.276	0.014
6000	12.2	5.95	0.203	0.198	0.193	0.010
5000	9.0	4.4	0.15	0.147	0.144	0.006
4000	6.1	2.95	0.102	0.095	0.094	0.008
3000	3.6	1.70	0.06	0.057	0.054	0.006
2500	2.5	1.2	0.042	0.040	0.038	0.004

From the above table the hysteresis losses in ergs per cm.^{3} were calculated, and the logarithms of the losses and of the inductions taken, as shown in Table II.

TABLE II.

Hysteresis Losses in Scale from Silicon Steel.

B	Hysteresis ergs per cm.^{3}	Log B	Log hyst	η ($x = 1.6$ assumed)
7500	33,700	3.875	4.528	0.0222
6000	23,570	3.778	4.373	0.0212
5000	17,580	3.699	4.245	0.0212
4000	11,475	3.602	4.060	0.0198
3000	6,595	3.477	3.819	0.0180
2000	4,640	3.398	3.667	0.0170
Average				0.0199

FIG. 5.

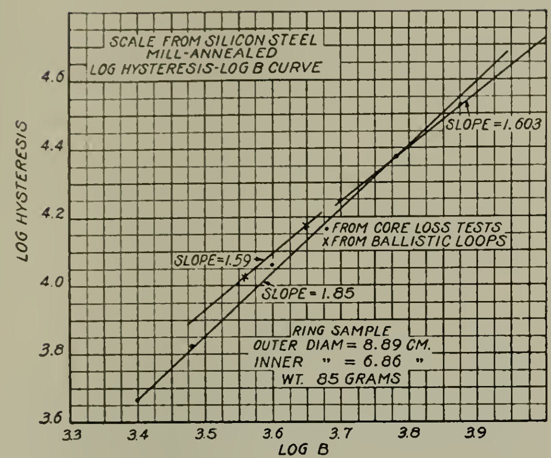
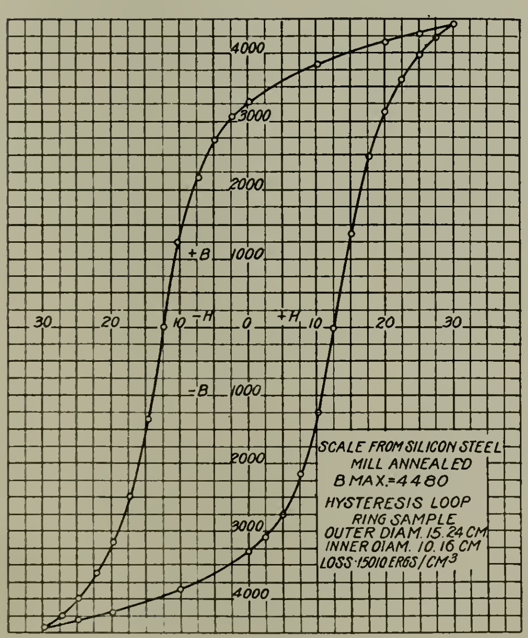

SCALE FROM SILICON STEEL
MILL-ANNEALED
LOG HYSTERESIS-LOG B CURVE
SLOPE = 1.603
FROM CORE LOSS TESTS
X FROM BALLISTIC LOOPS
SLOPE=1.59
SLOPE = 1.85
RING SAMPLE
OUTER DIAM = 8.89 CM.
INNER " = 6.86 "
WT. 85 GRAMS
LOG HYSTERESIS
LOG B
4.6
4.4
4.2
4.0
3.8
3.6
3.3
3.4
3.5
3.6
3.7
3.8
3.9

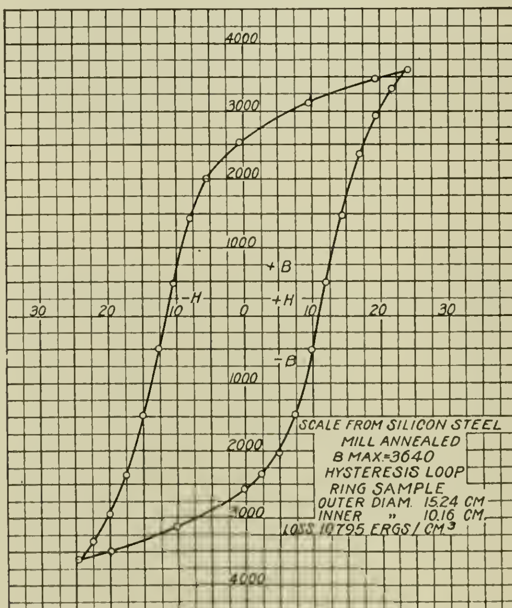
FIG. 6.


4000
3000
2000
+B
1000
30
20
10
-H
0
+H
10
20
30
-B
1000
2000
3000
4000
SCALE FROM SILICON STEEL
MILL ANNEALED
B MAX.=4480
HYSTERESIS LOOP
RING SAMPLE
OUTER DIAM. 15.24 CM
INNER DIAM. 10.16 CM
LOSS 15010 ERGS/CM3

A plot of the log hysteresis – log B is shown on Fig. 5.

In order to find the value of the constants in the Steinmetz equation, $h = \eta\ B^{1.6}$, the slope of the line log h – log B was next determined and evaluated by the $\Sigma\Delta$ method.[8] Taking all the above points, the slope of the line, which is the value of x in the equation, proves to be 1.83. Considering the points lying on the line, we obtain 1.85. As 1.6 is not claimed to be accurate at very low inductions, the most reasonable value is found by taking the three highest points. The slope of a line determined from this

FIG. 7.



point is 1.603, or practically 1.6, as has been found for a variety of magnetic materials.

In order to evaluate η and to have values comparable with constants for other materials, it is best to assume $x = 1.6$. The values of η so obtained are given in the last column of Table II. The average value is 0.0199. The average of the three highest points is 0.0216. From the nature of the tests the above results, especially at low values, are likely to be somewhat in error.

[8] "Engineering Mathematics," Steinmetz.

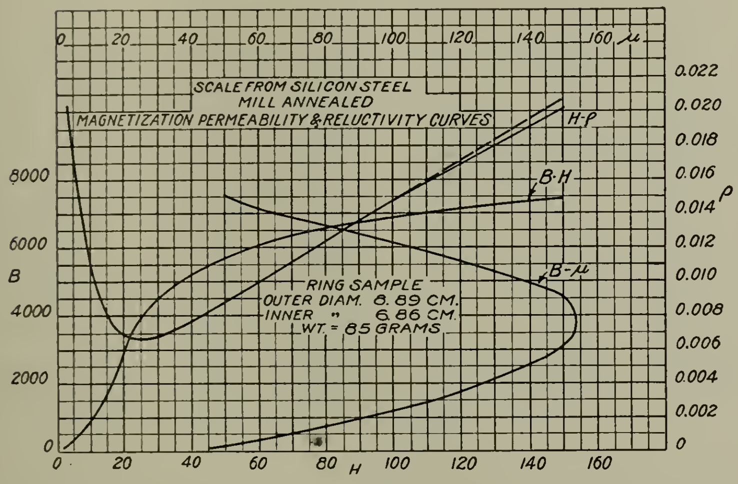
Hysteresis losses were also taken by the usual ballistic galvanometer method. Loops were obtained at $B = 4487$ and $B = 3639$, and are shown on Fig. 6 and Fig. 7 respectively. The integration of the loops gives values shown in Table III, wherein the logarithms of the values are included.

TABLE III.

Hysteresis Losses in Scale. Ballistic Tests.

B	Hysteresis ergs per cm.³	Log B	Log hysteresis	η (x = 1.6 assumed)
4480	15,010	3.651	4.176	0.0216
3640	10,795	3.561	4.033	0.0216

FIG. 8.



Obtaining the slope of the log h – log B line, we have 1.59. These points are shown, together with hysteresis points obtained from the core loss curve, on Fig. 5. Assuming $x = 1.6$ for the ballistic values, we find $\eta = 0.0216$, which agrees with the three upper points before mentioned. We may therefore, with reasonable accuracy, express the hysteresis loss of this sample as $h = 0.0216 B^{1.6}$.

Magnetization, Permeability and Reluctivity.

Two tests for magnetization curves were made and found to be within good agreement. The method of test was the common

one of reversing various currents in a magnetizing winding and noting flux change by means of a ballistic galvanometer. Results of these tests are given in Table IV, and the average of the two tests is plotted on Fig. 8. On this sheet are plotted the $B-H$, $B-\mu$, and reluctivity $H-\rho$ curves. The reluctivity gives practically a straight line from $H=40$, which condition, as before stated, has been found for various metals.

TABLE IV.

Magnetization Data of Scale from Silicon Steel.

H	B Test 1	B Test 2	B Average	$\mu = B/H$	$\rho = H/B$
150	7425	7555	7490	50.0	0.0202
140	7306	7566	7388	52.6	0.0190
130	7187	7332	7260	56.0	0.0179
120	7083	7190	7136	59.4	0.0168
110	6964	7054	7009	63.6	0.0158
100	6890	6920	6905	69.1	0.0145
90	6696	6781	6739	74.9	0.0134
80	6514	6600	6557	82.0	0.0122
70	6290	6380	6335	90.5	0.0110
60	6064	6121	6093	101.5	0.0099
50	5740	5770	5755	115.0	0.00868
40	5266	5283	5275	132.0	0.00766
30	4527	4497	4512	150.5	0.00665
20	2960	2991	2975	148.8	0.00675
10	918	879	899	89.9	0.0111
5	287.7	278	283	55.6	0.0177
3	149.0	144.7	147	49.0	0.0204
2	94.9	81.0	93	46.5	0.0215

Examination of Fig. 8 shows the reluctivity curve to be a straight line from $H=40$ to $H=105$, at which latter value the line bends slightly. From $H=105$ to the end the points also lie on a straight line. Taking the equation of this line as $\rho = \alpha + \sigma H$, evaluating the constants by the $\Sigma\Delta$ method, gives

From $H = 40$ to $H = 105$:—

$$\rho = 0.00289 + 0.000117\ H$$

$$\text{Saturation } B = \frac{1}{\sigma} = 8550$$

From $H = 105$ on:

$$\rho = 0.0033 + 0.000112\ H$$

$$\text{Saturation} = 8900$$

From these equations we may find the equations of the magnetization curves to be

From $H = 40$ to $H = 105$

$$B = \frac{H}{0.02289 + 0.000117\,H}$$

From $H = 105$ on:

$$B = \frac{H}{0.0033 + 0.000112\,H}$$

The maximum permeability of the material is about 154 at an induction $B = 3700$.

The results of these tests show two especially interesting features:

1. The loss in the scale itself apparently follows the Steinmetz law.

2. From maximum permeability the reluctivity curve of the scale is practically a straight line.

The slight bend in the reluctivity curve at $H = 105$ is accounted for in the same manner as for sheet steel. The scale itself consists of a mixture of iron, silicon, oxides, and impurities, and is not magnetically alike throughout.

V. Distribution of Flux and Losses in Steel and Scale Calculated from Test Results on Scale Alone.

Having now seen that the scale from steel follows the magnetic laws under discussion, we now desire to determine, by calculations, the nature of its influence on the measured magnetic values and losses of steel upon which scale appears.

If we take a typical magnetization curve representing silicon steel as entirely free from scale and entirely magnetically homogeneous throughout we may expect the following characteristics:

Saturation: $B = 20{,}000$.

Maximum Permeability: $\mu = 5000$, occurring at $B = 5000$. Then at maximum permeability $H = \frac{5000}{5000} = 1$. In the equation of the magnetization curve, $B = \frac{H}{\alpha + \sigma H}$, σ would then be $\frac{1}{20{,}000}$, or 0.00005.

At $H = 1$, $\rho = \frac{1}{5{,}000} = 0.0002$.

Also $\rho = \alpha + 0.00005\,H$.

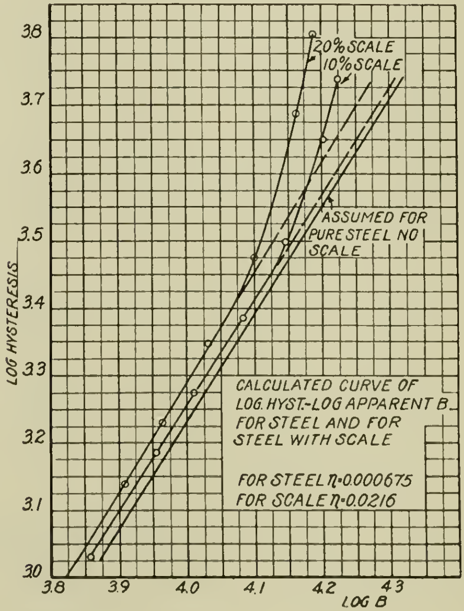
From above, $\alpha = 0.0002 - 0.00005 = 0.00015$.

For the typical magnetization curve beyond maximum permeability we then have:

$$B = \frac{H}{0.00015 + 0.00005\,H}$$

From this equation we obtain values of B corresponding to various values of H as shown in Table V, in which table the values of B corresponding to the same values of H are given for scale

FIG. 9.



from silicon steel, which values are taken from Fig. 8 and accompanying data in Table IV.

Assuming a total cross-section area of steel and scale as 1 cm.^{2}, of which 90 per cent. is steel and 10 per cent. is scale, the flux in the steel and scale are given in Table V, columns 4 and 5 respectively. The total flux, or apparent B, of the mixture is given in column 6.

TABLE V.

Values of Flux in Steel and in Scale for 20 per cent. Scale.

H	B In steel	B In scale	Flux in 0.9 cm.^{2} of steel	Flux in 0.1 cm.^{2} of scale	Total flux or apparent B of mixture
2	8,000	93	7,200	9	7,210
3	10,000	147	9,000	15	9,015
4	11,420	200	10,300	20	10,320
6	13,330	400	12,100	40	12,140
10	15,400	900	13,880	90	13,970
20	17,400	2,975	15,680	298	15,980
30	18,200	4,512	16,400	451	16,850

We have previously found that in the Steinmetz equation for hysteresis an average of certain tests gives a value of $\eta = 0.000675$ for silicon steel. The present investigation shows that for scale η may be taken as 0.0216. Assuming the hysteresis law to hold throughout the range for steel free from impurities, we obtain for the densities of Table V hysteresis losses as given in Table VI. In this table are also given the losses for 0.9cm.^{3} of steel and 0.1 cm.^{3} of scale, which, added together, give the total hysteresis losses per cm.^{3} of the mixture. The logarithms of the hysteresis losses and logarithms of apparent densities are also tabulated. Plotting the log hysteresis and log B, we find on Fig. 9 that the curve is a straight line to about $B = 12{,}000$, beyond which the increase in hysteresis is greater than if the 1.6 law held for the mixture. This agrees with observations made by several authors, and might easily account for the apparent increase of hysteresis in sheet steel at high inductions, concerning which much has been

TABLE VI.

Hysteresis Loss for Steel, Scale and Mixture with 10 per cent. Scale.

H	Hyst. in steel per cm.^{3}	Hyst. in steel 0.9 cm.^{3}	Hyst. in scale per cm.^{3}	Hyst. in scale 0.1 cm.^{3}	Total hyst. in 1 cm.^{3} of mixture	Log hyst.	Log of apparent B
2	1183	1065	29.4	3	1068	3.029	3.858
3	1695	1525	62.0	6	1532	3.185	3.955
4	2090	1880	104	10	1890	3.277	4.013
6	2690	2420	318	32	2452	3.389	4.084
10	3390	3050	1130	113	3163	3.500	4.146
20	4130	3700	7800	780	4480	3.651	4.204
30	4420	3980	14.950	1495	5475	3.738	4.226

For steel $\eta = 0.000675$
For scale $\eta = 0.0216$

written. For the straight part of the curve the slope is 1.59, or approximately 1.6. Assuming the hysteresis exponent to be 1.6, the higher inductions would show the increase as given in Table VII.

TABLE VII.

Values of η when Steel Contains 10 per cent Scale.

B	η of mixture ($x = 1.6$)	Ratio η to average η	Average ratio of sheet steel found from test values
7210	0.000721		1.00
9015	0.000716		1.01
10320	0.000716	1.00	1.04
12140	0.000716		1.13
13970	0.000737	1.03	1.24
15980	0.000842	1.17	
16850	0.000946	1.32	

Average η for first four points = 0.000717

The increase of η here given is not as great as found by test on sheet steel itself, but shows the same nature and rate of increase. In silicon sheet steel the scale and other impurities in the steel itself might easily be more than 10 per cent. of the volume, and the theoretical curve would thereby show greater increase of η and check the test results much closer.

TABLE VIII.

Values of Flux in Steel and in Scale for 20 per cent. Scale.

H	B In steel	B In scale	Flux in 0.8 cm.² of steel	Flux in 0.2 cm.² of scale	Total flux or apparent B of 1 cm.² of mixture
2	8,000	93	6,400	18	6,420
3	10,000	147	8,000	20	8,030
4	11,420	200	9,140	40	9,180
6	13,330	400	10,670	80	10,750
10	15,400	900	12,320	180	12,500
20	17,400	2,975	13,920	595	14,500
30	18,200	4,512	14,560	900	15,500

Table VIII gives similar calculations, assuming 20 per cent. of the cross-section area to be scale, and Table IX gives the hysteresis

TABLE IX.

Hysteresis Loss in Steel, Scale and Mixture with 20 per cent. Scale.

H	Hyst. in steel per cm.³	Hyst. in 0.8 cm.³ steel	Hyst. in scale per cm.³	Hist. in scale 0.2 cm.³	Hyst. in mixture	Log hyst.	Log apparent B
2	1183	947	29.4	6	953	2.979	3.808
3	1695	1358	62.0	12	1370	3.137	3.905
4	2090	1672	104	21	1690	3.228	3.963
6	2690	2153	318	64	2220	3.346	4.031
10	3390	2715	1130	226	2940	3.468	4.097
20	4130	3310	7800	1560	4870	3.688	4.161
30	4420	3540	14.950	2990	6530	3.815	4.190

For steel $\eta = 0.000675$

For scale $\eta = 0.0216$

loss in steel, scale, and the mixture, assuming 20 per cent. scale. Table X gives us values of η for the mixture, together with the amount of increase of η with increased induction. Comparing with test values of sheet steel, we find the increase of η with increased induction may be represented by steel and scale taken together, in which case the amount of scale is between 10 per cent. and 20 per cent., which we know represents the facts.

TABLE X.

Values of η When Steel Contains 20 per cent. Scale.

B	η	Ratio η to average η
6.420	0.000771	
8,030	0.000771	1.00
9.180	0.000771	
10,750	0.000786	1.02
12,500	0.000818	1.06
14,500	0.00105	1.36
15.500	0.00130	1.68

Average η for first three points = 0.000771

VI. Tests of Iron and Cobalt Separately and Together to Show Properties of Homogeneous and Heterogeneous Magnetic Materials.

In order to show more clearly the behavior of magnetic phenomena on homogeneous and heterogeneous materials, tests were made to determine the properties of as nearly pure materials as could be obtained. A solid ring of iron and a solid ring of cobalt were selected. Solid rings were tested to obtain most satisfactory magnetic flux paths and to eliminate scale as much as possible. The errors due to shape of specimen of the ring sample are not great and are practically the same for both specimens and are

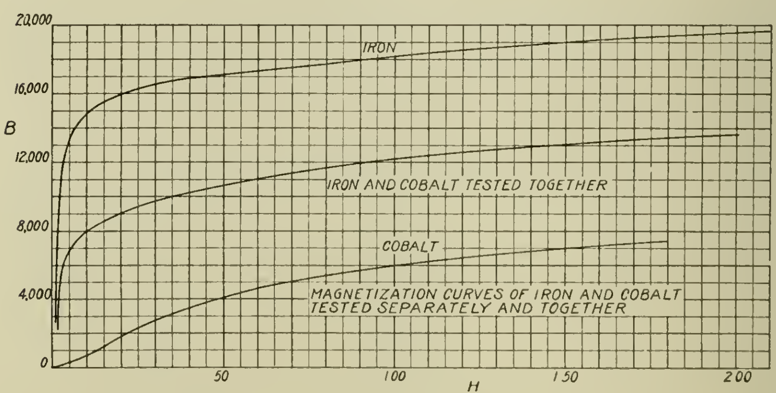
therefore negligible. The principal dimensions of the samples are as follows:

	Cobalt ring	Iron ring
Outer diameter..	3.176 cm. (1.25 inch)	3.178 cm. (1.25 inch)
Inner diameter...	2.223 cm. (0.875 inch)	2.223 cm. (0.875 inch)
Mean diameter...	2.695 cm. (1.06 inch)	2.7005 cm. (1.06 inch)
Weight..........	31.15 grammes (0.068 pound)	28.01 grammes (0.062 pound)
Volume..........	3.534 cm.^{3} (0.216 cubic inch)	3.562 cm.^{3} (0.217 cubic inch)
Section..........	0.4165 cm.^{2} (0.0646 square inch)	0.415 cm.^{2} (0.0644 square inch)
Specific gravity..	8.81	7.86

Magnetization and Reluctivity.

The test on the iron ring made by the usual ballistic galvanometer method gave results as shown in Table XI.

FIG. 10.

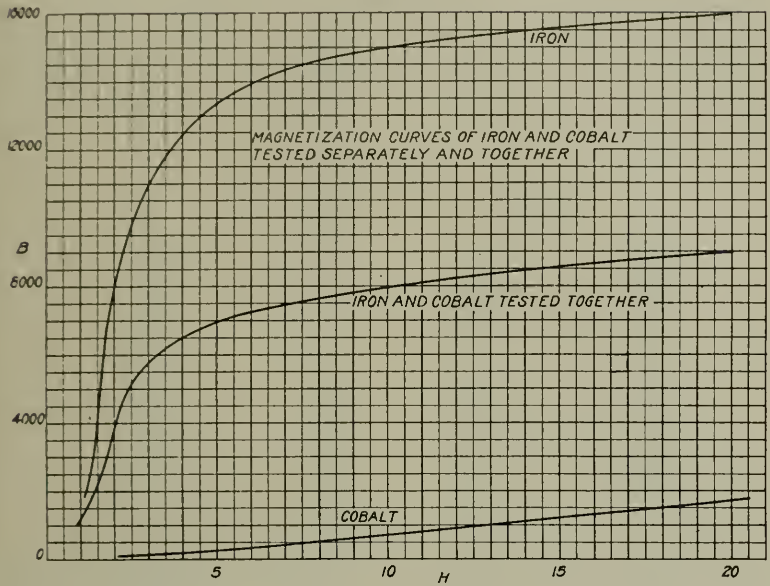


Results on the cobalt ring are given in Table XII, and in Table XIII we have test results made by taking both rings and testing them together as a single material.

The plotted results are given on Fig. 10. As the inductions at low values of H are required for analyses of hysteresis data, the lower portion of the magnetization curves are given on a larger scale in Fig. 11.

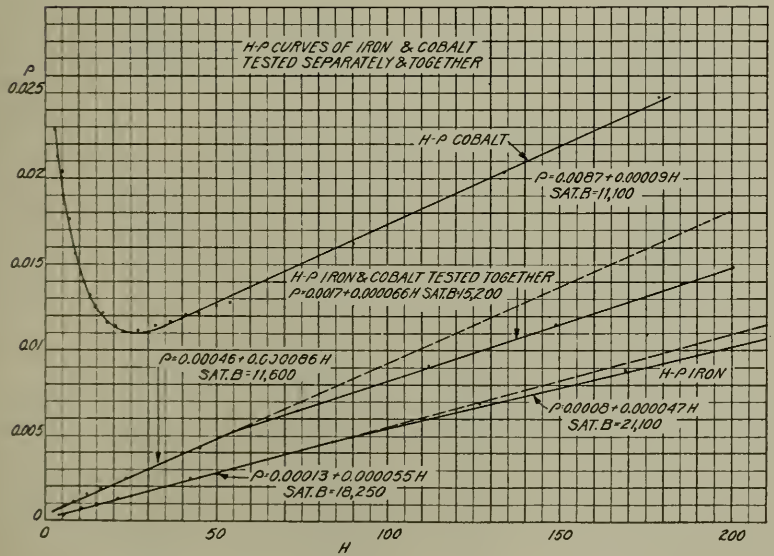
It would naturally be expected that, as the rings are of approximately the same section, the test on the two taken together would give an induction for any value of H which would be the mean of the values for the component parts. This may be shown by Table XIV, wherein test values from the iron, cobalt, and mix-

FIG. 11.



16000
12000
B
6000
4000
0
IRON
MAGNETIZATION CURVES OF IRON AND COBALT TESTED SEPARATELY AND TOGETHER
IRON AND COBALT TESTED TOGETHER
COBALT
5
10
H
15
20

FIG. 12.



H-P CURVES OF IRON & COBALT TESTED SEPARATELY & TOGETHER
P
0.025
0.02
0.015
0.01
0.005
0
H-P COBALT
P=0.0087+0.00009H
SAT.B=11,100
H-P IRON & COBALT TESTED TOGETHER
P=0.0017+0.000066H SAT.B=15,200
P=0.00046+0.000086 H
SAT.B=11,600
H-P IRON
P=0.0008+0.000047H
SAT.B=21,100
P=0.00013+0.000055H
SAT.B=18,250
0
50
100
H
150
200

ture are tabulated with the calculated density in the mixture, assuming the section of the two rings to be the same.

The interesting fact brought out by these tests is shown by plotting the reluctivity curves such as given on Fig. 12. Here we find that there is no indication of the change of slope in the line for the cobalt curve.

TABLE XI.

Magnetization Test of Iron Ring.

H	B	$\mu = B/H$	$\rho = H/B$
212	19,750	93	0.0107
170	19,280	114	0.0088
127	18,680	147	0.0068
84	17,930	213	0.0047
42	16,980	402	0.00247
21	16,130	765	0.00130
15.5	15,560	1,007	0.000995
10.4	15,010	1,450	0.000693
5.2	13,490	2,600	0.000385
4.17	12,670	3,350	0.000330
3.12	11,300	2,630	0.000276
2.09	8,220	3,930	0.000254
1.75	7,040	4,040	0.000248
1.67	5,370	4,040	0.000311
1.46	3,780	2,590	0.000388
1.36	2,920	2,150	0.000465
1.25	2,260	1,810	0.000555
1.10	1,830	1,670	0.000601
0.84	1,000	1,180	0.00084

TABLE XII.

Magnetization Test of Cobalt Ring.

H	B	$\mu = B/H$	$\rho = H/B$
179	7,440	41.5	0.0242
135	6,750	50.0	0.0200
91	5,650	62.5	0.0161
36.4	3,160	86.7	0.0115
27.2	2,460	90.5	0.0110
54.3	4,310	79.0	0.0126
45.0	3,732	83.0	0.0121
20.45	1,832	89.6	0.0112
16.28	1,385	83.1	0.0120
12.75	980	76.8	0.0130
9.10	592	65.1	0.0154
5.46	272	49.8	0.0201
3.12	140	45.0	0.0223
2.09	84	40.2	0.0249

TABLE XIII.

Magnetization Test of Iron Ring and Cobalt Ring Taken Together.

H	B	$\mu = B/H$	$\rho = H/B$
201	13,680	68	0.0147
186	13,490	73	0.0138
149	13,100	88	0.0114
112	12,450	111	0.0090
74	11,550	156	0.0064
45	10,510	234	0.00428
23.3	9,280	398	0.00252
15.8	8,600	544	0.00184
12.0	8,200	684	0.00147
8.15	7,610	934	0.00107
5.65	7,190	1,270	0.00079
4.52	6,770	1,495	0.00070
3.76	6,390	1,700	0.00059
3.01	5,780	1,920	0.00052
2.25	4,690	2,080	0.00048
1.88	3,650	1,940	0.00052
1.50	2,190	1,460	0.00069

The curve of the iron itself shows a slight bend or change of slope, indicating that the iron ring was very nearly homogeneous magnetically, but not entirely so.

TABLE XIV.

Comparison of Flux Densities in Iron, Cobalt and Mixture.

	B			
H	In iron by test	In cobalt by test	In both by test	Calculated average
150	19,000	7,000	13,000	13,000
100	18,200	5,900	12,200	12,050
50	17,100	4,100	10,700	10,600
20	16,000	1,800	9,000	8,900
10	14,800	700	7,900	7,750
5	13,400	300	6,900	6,850
2	8,000	100	4,000	4,000

Examining the curve for the iron and cobalt tested together, we see that at about $H = 55$ there is a sharp and decided bend, such as has been found in so many cases. This curve, while agreeing with the calculated results, is plotted from test results and is not deducted mathematically by assuming any theory. It is to be noted that the indicated saturation of the lower part of the curve

for iron and cobalt together is close to that indicated as the ultimate saturation of the cobalt. It is naturally somewhat higher, due to the effect of the iron.

Hysteresis Losses.

Hysteresis tests were made by means of a ballistic galvanometer. The results of the iron ring are given in Table XV.

TABLE XV.

Hysteresis Losses in an Iron Ring
(Losses in ergs per cm.^{3})

B	H	Hyst.	Log B	Log hyst.	η ($x = 1.6$ assumed)	
15,000	10.71	7,900	4.176	3.898	0.00164	
12,000	3.58	4,865	4.079	3.687	0.00145	Average 0.00145
10,000	2.455	3,510	4,000	3.545	0.00140	
6,000	1.758	1,614	3.778	3.308	0.00145	
4,000	1.505	873	3.602	2.941	0.00150	
1,000	0.890	73.8	3.000	1.868	0.00117	

The log h – log B curve is plotted on Fig. 13. The slope of the line, using all points, is 1.65; the upper points give nearer 1.6. The coefficient η is calculated on the basis of 1.6 for purposes of comparison. The results of cobalt ring are given in Table XVI.

TABLE XVI.

Hysteresis Losses in a Cobalt Ring.
(Losses in ergs per cm.^{3})

B	Hysteresis	Average hysteresis	Log B	Log hysteresis	η ($x = 1.6$ assumed)	
4000	11,020; 10,950	11,000	3.603	4.041	0.0190	Average 0.0163
2000	3210; 3080	3150	3.301	3.498	0.0168	
1000	810; 848	830	3.000	2.919	0.0131	
500	203	203	2.699	2.308	0.0088	

The log h – log B curve is shown on Fig. 13: the slope of the line using all points is 1.85. Lack of time prohibited further tests to check these results. It has been shown that the exponent for cobalt is 1.60; and, while this figure would be more satisfactory to quote here, I prefer to give the data as obtained. This high value

of the exponent does not interfere with the present demonstration.

The results of hysteresis tests on the iron and cobalt rings together are given in Table XVII.

FIG. 13.

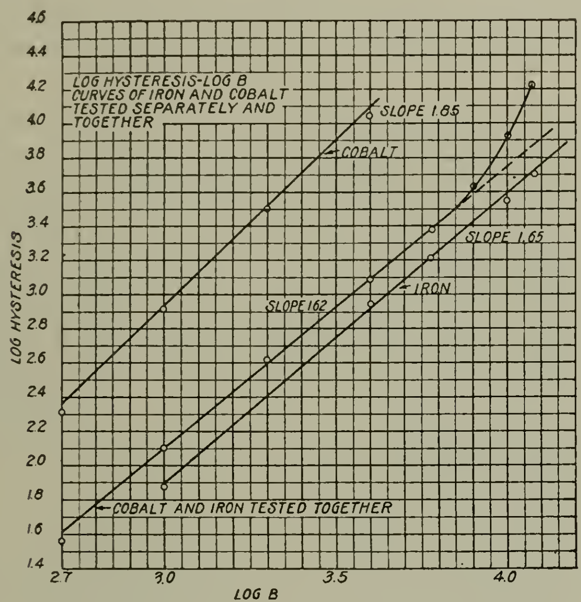


TABLE XVII.

Hysteresis Losses in an Iron and a Cobalt Ring Tested Together.
(Losses in ergs per cm.³)

B	Hyst.	H	Log B	Log hyst.	η ($B = 1.6$ assumed)	
12,000	17,470	101.1	4.079	4.242	0.00519	
10,000	8,975	38.6	4.000	3.953	0.00358	
8,000	4,110	11.2	3.903	3.614	0.00234	
6,000	2,360	3.41	3.778	3.373	0.00212	Average 0.0021
4,000	1,228	2.055	3.602	3.089	0.00212	
2,000	409	1.523	3.301	2.612	0.00213	
1,000	126.2	1.191	3.000	2.102	0.00200	
500	35.9	0.885	2.699	1.556	0.00172	

Here we find that the plotted results on Fig. 13 give a line having a slope of 1.62 (or approximately 1.6) to $B = 6000$, beyond which we again find the indicated abnormal increase of hysteresis

loss. The deviation from the straight line is greater for this curve of the two metals than could possibly be considered as a characteristic of either of the metals themselves.

In order to show how the results on the two rings together compare with values calculated from the characteristic of the rings taken separately, we find a good agreement. The hysteresis losses are plotted on Figs. 14 and 15. In Table XVIII, column 1 shows

Table XVIII.

H	B_{Fe}	B_{Co}	B mixture		Hysteresis Fe	Hysteresis Co	Hysteresis of mixture	
			Calculated	Test			Calculated	Test
101.1	18200	5900	12050	12000	11900*	23100†	17500	17470
38.6	16800	3300	10050	10000	9770‡	7750	8760	8975
11.2	15100	800	7950	8000	8000	500	4250	4110
3.41	11700	150	5925	6000	4600	25	2315	2360
2.055	8000	100	4050	4000	2460	10	1235	1228
1.52	4000	50	2025	2000	873	...	435	409
1.191	2200	..	1100	1000	300	...	150	126.2
0.885	.....	..	....	500	203	...	100	35.9

* Calculated by extrapolation of $B-\eta$ curve. η taken as 0.0018.
† Calculated by extrapolation of $\eta=0.021$.
‡ Calculated by extrapolation of $\eta=0.0017$.
All other results from results Figs. 14 and 15.

the H values of the loops taken on both rings together. Columns 2 and 3 give inductions in iron and cobalt taken from the magnetizing curves on Figs. 10 and 11. The calculated density and the observed density for the loops are given in columns 4 and 5. Columns 6 and 7 give hysteresis results in iron and cobalt at their respective densities, taken from Figs. 14 and 15. Column 8 gives calculated hysteresis losses of the mixture, they being the mean of columns 6 and 7. Column 9 gives the observed hysteresis loss of the mixture from the tests.

VII. Application of Data in Calculating Magnetic Losses.

We have shown that the usual deviations from the reluctivity and hysteresis laws may be accounted for by the fact that the materials are not homogeneous. It therefore is evident that to expect the laws to hold for all mixtures is as inconsistent as to take the compressive strength of a brick and use that figure to calculate the strength of a brick wall having, say, 10 per cent. mortar.

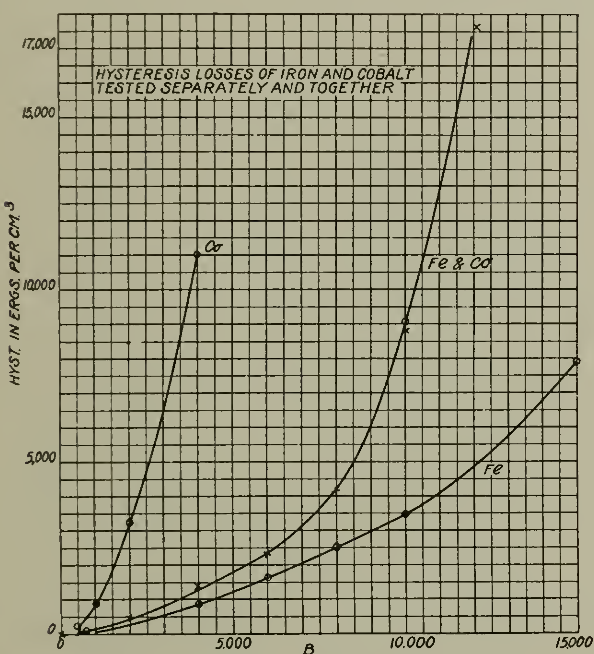
In the case of sheet steel, for any given magnetization the per-

meability and hysteresis losses must be calculated for steel and scale separately and combined in correct proportions, especially if accuracy is desired at high inductions.

For purposes of illustration let us assume that it is desired to obtain the ratio of hysteresis losses in silicon steel at inductions of $B = 15,000$ and $B = 10,000$.

If the material in question were homogeneous throughout and

FIG. 14.



the hysteresis loss followed the Steinmetz law, between $B = 15,000$ and $B = 10,000$, the ratio of hysteresis loss, R_h, would be:

$$R_h = \left(\frac{15,000}{10,000}\right)^{1.6} = 1.91.$$

Assuming 10 per cent. scale, the densities in the iron, the scale, and the mixture may be taken for various values of H from Table V.

Plotting a curve, Fig. 16, giving relation of apparent B in the material and the B in scale, and finding therefrom the actual flux density in the steel itself, we obtain values in Table XIX.

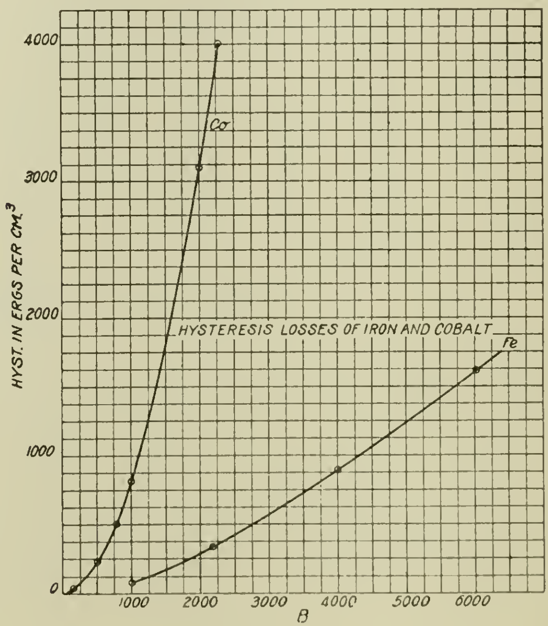
TABLE XIX.

Distribution of Flux Densities in Steel and Scale.

B (apparent)	B in scale	Flux in 0.1 cm.^{2} of scale	Flux in 0.9 cm.^{2} of steel	B in steel
15,000	1,500	150	14,850	16,500
10,000	200	20	9,980	11,090

Table XIX shows that when testing at $B = 15{,}000$ and $B = 10{,}000$ the actual density in the steel is 16,500 and 11,100, and the

FIG. 15.



ratio of densities for the scale is very much greater than the ratio of apparent densities.

Assuming the 1.6 law to hold rigidly for both steel and scale, and taking the values of Table XIX, we should expect, when testing at $B = 15{,}000$ and $B = 10{,}000$, ratios as follows:

Hyteresis ratio for steel:

$$R_h = \left(\frac{16{,}500}{11{,}090}\right)^{1.6} = 1.89.$$

Hysteresis ratio for scale:

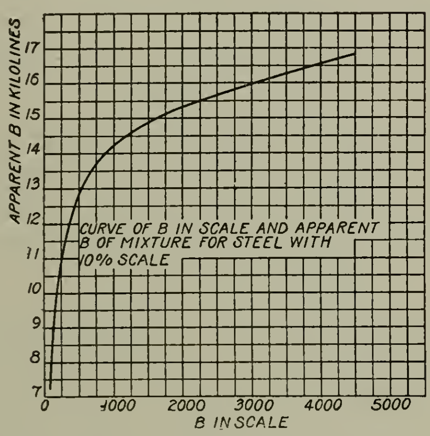
$$R_h = \left(\frac{150}{20}\right)^{1.6} = 25.$$

For 90 per cent. steel and 10 per cent. scale the hysteresis ratio of the mixture would be:

$$R_h = \frac{(90 \times 1.89) + (10 \times 25)}{100} = 4.20.$$

While our data on scale are limited, and the varying percentages of scale would affect results, yet the figures obtained represent test results reasonably well.

FIG. 16.



VIII. Investigation to Determine Losses in Unsymmetrical Loops.

Shortly after the announcement of the 1.6 law the statement was made that "the energy dissipated by hysteresis depends only upon the difference of the limiting values of magnetic induction, between which the magnetic cycle is performed, but not upon their absolute values, so that the energy dissipated by hysteresis is the same so long as the amplitude of the magnetic cycle is the same." [9] This has been written as

$$= h\left(\frac{B_1 - B_2}{2}\right)^{1.6}$$

[9] *Trans. A. I. E. E.*, vol. ix, 1892, p. 633

where B_1 and B_2 are the values between which the magnetism varies. Tests were made which apparently justified and substantiated this statement, and the results were published.

In these tests the range of flux values was comparatively small as compared with the range of values of the mean inductions, and the materials employed were magnetically hard and characterized by high hysteresis loss.

It has recently been observed that when materials are taken through unsymmetrical hysteresis cycles there is, contrary to earlier writers, apparently more energy dissipated than when taken through the symmetrical loop of the same amplitude. By an unsymmetrical loop is meant the hysteresis loop obtained when the magnetism is carried through a cycle in which the limiting values of flux are different in amount, or, in other words, in which the mean value of the flux differs from zero. The recent statements, then, are to the effect that when B_2 is different in amount from B_1 the loss is greater than when $B_2 = -B$.

Some investigations have been made and the results published by Mr. Rosenbaum [10] and Dr. F. Holm.[11] Both investigations led to the conclusion that the hysteresis loss is greater for the unsymmetrical loops than for the symmetrical loops of the same amplitude.

Such variation of magnetism occurs in many places, such as in an inductor generator, etc. The same phenomena occur in the field cores of machines where the ratio of flux change is so small that the loss is not a consideration.

However, in these cases the shapes of the loops are of value in determining the regulation of machines in which the magnetic cycle of the field cores is a determining factor.

The unsymmetrical hysteresis loop is also in evidence in all material magnetized by current from a rectifier, etc.; in short, in all circuits where alternating current and direct current are superimposed. A specific case of interest is the well-known fact that core losses of certain machines have been found to exceed calculated values, unless percentages are added. The fact that high-frequency flux ripples in the teeth give a higher hysteresis loss than the same flux change with zero as a mean value of in-

[10] *Jour. I. E. E.*, vol. 48, 1912, pp. 534 545.

[11] *Zeit. des ver. deut. Ing.*, vol. 56, 1912, pp. 1746 1751.

duction would in part account for this additional loss. This is especially noticeable in the case of induction machines.

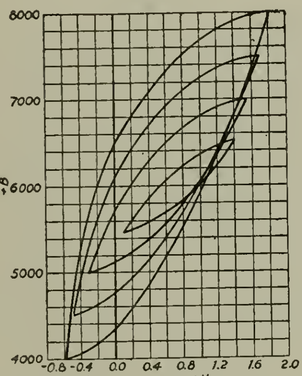
In the present investigation tests were made which led to these interesting deductions:

1. The hysteresis loss in an unsymmetrical loop is greater than the loss in a symmetrical loop of the same difference of limiting values of flux.[12]

2. Within the limits of the tests, the losses of loops having the same difference of limiting values of flux were found to increase with a definite power of the average or mean flux density.

3. The increased loss as a definite power of the mean flux

FIG. 17.



Group of unsymmetrical loops about a common centre. $B_m = 6000$. Medium silicon steel.

density was found to be the same for any difference of limiting flux values or range of the loops.

4. With any given value of mean density the increased losses with increased range were found to increase as definite power of the range. irrespective of the mean value of density.

Fig. 17 shows a group of unsymmetrical loops about a common centre, $B_m = 6000$.

Fig. 18 shows a group of loops of the same range of flux change, but having different values of mean induction.

We have found that we could write an equation to express the loss in any loop. The general equation is:

$$h = (\eta + \alpha B_m{}^y)B^x$$

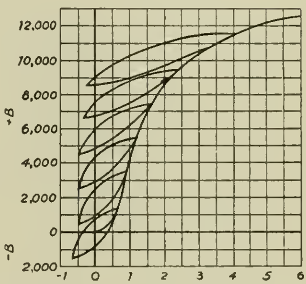
[12] This has been again confirmed by a valuable investigation made by Messrs. L. W. Chubb and T. Spooner. See *Proc. A. I. E. E.*, October, 1915, pp. 2321–2342.

wherein η and x are the constants of the Steinmetz law, α is a coefficient depending upon the material, and y a power of the mean density. Tests satisfied the equation in the form:

$$h = (\eta + \alpha B_m^{1.9})B^{1.6}$$

The details of this portion of our general investigation have been published elsewhere [13] and need not be reproduced here; it is sufficient to say that with an accumulation of more data the equation for any loop which we give may or may not be verified as a law. However, it seems very definitely shown the loss increases as the mean induction is raised.

FIG. 18.



Group of unsymmetrical hysteresis loops. Medium silicon steel. Loops of amplitude. B = ± 1500 with various values of B_m.

CONCLUSIONS.

From this investigation we find additional evidences that the hysteresis law as given by Dr. Steinmetz in 1892 is confirmed, and his equation $h = \eta B^{1.6}$ correctly represents the hysteresis loss over a wide range of densities up to the highest recorded for pure or magnetically homogeneous materials. While some results which have been published showing much greater losses at high induction than given by the law are incorrect, due to erroneous calculations, however, most results showing greater losses at high inductions are taken from test data obtained on heterogeneous material whose component parts, if tested separately, would follow the law.

It may be pointed out that if two components of a heterogeneous material followed the 1.6 law, and with increasing H, the induction in the two increased at the same rate, the resultant

[13] *Proc. A. I. E. E.*, October, 1915, pp. 2275–2297.

must also show an increased loss following the 1.6 law. The deviations noted are due to the fact that with increasing magnetization the induction in two materials does *not* increase at the same rate throughout. Therefore, as they do not, the measured hysteresis loss could not be expected to follow any law. The difference in materials employed and the difference of their respective volumes may and probably does introduce an infinite variety of possible combinations which prohibits a rational law.

The same reasoning applies to the reluctivity law of Kennelly, which is also confirmed by this investigation.

Test results have been given in considerable detail for the benefit of any who may be interested and may wish to draw conclusions other than those set forth in this paper.

Why the hysteresis loss increases as the 1.6 power of the density has, to our knowledge, never been explained. That it cannot hold at very low densities has been shown by Dr. Steinmetz himself. The fact remains, however, that our knowledge has been greatly augmented by the announcement of this useful discovery, and careful research is still showing that the law as stated correctly represents the hysteresis losses in magnetic materials.

In conclusion, the author desires to acknowledge much excellent coöperation. The work was attempted at the instigation of Dr. C. P. Steinmetz, for whose interest and assistance the author is greatly indebted. The writer also desires to thank Mr. L. T. Robinson for helpful suggestions and for placing the facilities of his laboratory at the author's disposal. In this laboratory much of the testing was done by Mr. S. L. Gokhale. The testing of steel scale was done in Mr. A. McK. Gifford's laboratory by Mr. Max. G. Newman.

Acknowledgment is also due to Mr. J. P. Duncombe for much valuable assistance throughout the process of this investigation.

SCHENECTADY, N. Y.,
November 1, 1915.

APPENDIX.

IX. Additional Properties of Scale from Silicon Steel.[14]

While tests described in Section IV of this paper were being made it seemed feasible to take the opportunity to make a further

[14] Some results of the investigation of steel scale have been used by the author in connection with a graduate thesis submitted to the University of Illinois and are published here with the permission of that institution.

study of the properties of scale as a matter of general interest and also as it has possibilities as a material for certain constructions.

Skin Effect.

The fact that scale is thin and has fairly good permeability and high resistivity places it as a desirable material for cores in machines and transformers of high frequency. The resistivity being high and the permeability being lower than that of ordinary steel give deeper penetration as regards skin effect, which is also an important consideration. Assuming the scale as carrying flux, the effective depth of penetration, l_p in cm., would be, according to the Steinmetz formula:

$$l_p = \frac{3570}{\sqrt{\lambda \mu f}}$$

wherein

λ = electrical conductivity.
μ = magnetic permeability.
f = frequency in cycles per sec.

The permeability varies, of course, with the flux density. We may assume for permeability a value $\mu = 60$. The average conductivity is $\frac{1}{126.2} + 10_6 = 7920$. At 10,000 cycles

$$l_p = \frac{3,570}{\sqrt{7920 \times 60 \times 10,000}} = 0.0518 \text{ cm.}$$

Assuming the thickness of the scale is 0.0064 cm. l_o, or ½ of the thickness, is 0.0032. This shows the penetration l_p is much greater than ½ thickness l_o, therefore there is no appreciable skin effect at 10,000 cycles. The maximum allowable thickness of scale which has no appreciable skin effect at 10,000 cycles would be 0.1036 cm. (0.0408 inch). The maximum frequency at which no appreciable skin effect would be in evidence would be found by letting $l_p = 0.0032$ and solving for f, which gives 2,600,000 cycles.

Properties at High Frequency.

Punchings of the same size as described in Section IV, but of less weight, were built up into a test sample for determining the properties at high frequency. A test was made at 10,000 cycles, but the results obtained were not at all consistent. Tests were

made at 97,000 cycles and 50,000 cycles, and repeated trials gave close checks with the first tests. The results are given on Fig. 19, from which Table XX was computed.

FIG. 19.

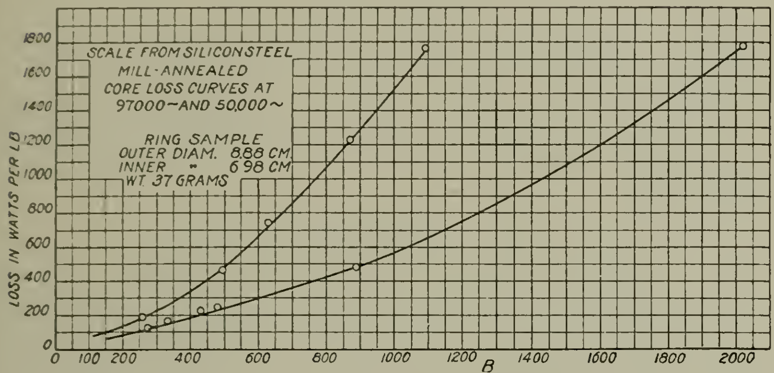


TABLE XX.

Losses in Scale from Silicon Steel at High Frequencies.

	Hyst. loss watts per pound		Loss per cycle		Loss per cycle 97,000 cycles	
B	97,000 cycles	50,000 cycles	97,000 cycles	50,000 cycles	Hyst.	Eddy
1,000	1,540	570	0.0159	0.0114	0.0066	0.0093
900	1,290	490	0.0133	0.0098	0.0061	0.0072
800	1,060	420	0.0109	0.0084	0.0057	0.0052
700	860	360	0.00887	0.0072	0.00542	0.00345
600	670	300	0.00691	0.0060	0.00503	0.00188
500	500	250	0.00515	0.0050	0.00484	0.0003

B	Hyst. in ergs per cycle per cm.³	η ($x = 1.6$ assumed)
1,000	806	0.0128
900	745	0.0142
800	696	0.0155
700	662	0.0182
600	615	0.0223
500	590	0.0283

It will be remembered that the value of η taken from the 60- and 30-cycle core-loss curves and the hysteresis loops gave a value of 0.0216.

The results are practically self-explanatory. Values of η, assuming $x = 1.6$, are given, although it would not be expected that the 1.6 law would hold rigidly at these low inductions.

Eddy-current Losses.

For the core-loss curves the eddy losses were found to be as shown in Table I. These losses are not consistent, as good results would not be expected by the method of test used and the high hysteresis to be subtracted from the core loss, which is mostly hysteresis. The eddy losses are high, which is probably due to the fact that the sample was taken as a bulk, with no effort to insulate laminations from each other. The eddy loss figures in Table I are therefore not to be considered as reliable, although sufficiently so to use for hysteresis determinations in the table wherein they were so used.

SCALE FROM VACUUM-ANNEALED STEEL.

Physical Appearance and Size of Samples.

The scale from vacuum-annealed steel appears to be much smoother than scale from mill-annealed steel. It is apparently tougher and more flexible. It is clean and very much whiter than the usual scale. One side is a dull grayish white, while the other side has a brighter shine and closely resembles silver. Two samples were tested, both of which were made up of ring punchings 0.0056 cm. (0.0022 inch) thick. One sample measured, outer diameter 15.25 cm. (6 inches), inner diameter 10.15 cm. (4 inches); the other sample was, outer diameter 8.89 cm. (3.5 inches), inner diameter 6.86 cm. (2.7 inches).

Specific Gravity.

The first determinations gave a specific gravity of 5.54 for both mill-annealed and vacuum-annealed scale. Core-loss and hysteresis tests were calculated on this basis. Subsequent study of the material led to the belief that this figure was low for scale from vacuum-annealed steel, and the analyses were repeated. The figure 5.54 was confirmed for the mill-annealed scale, but the vacuum-annealed product gave a more consistent figure of 6.07 at 15.5° C. The gravity may therefore be considered approximately 6.0. The core-loss curves and hysteresis loops have not been altered, as the results in ergs, upon which analyses of results are based, are the correct figures.

The magnetization curves also include assumptions of specific gravity = 5.54, but the error is much less than the variation in

material, and consequently allowed to stand as originally calculated. The steel from which the scale was taken has a specific gravity of practically 7.5 after vacuum anneal as well as after mill anneal.

Chemical Analysis.

The first analysis of this material gave the following results:

Si	7.03
S	0.148
Mn	0.43
C	0.054

An analysis for oxygen gave 0.73 per cent., but this is undoubtedly not correct.

A later and reliable analysis gave:

Si	5.72	5.48
S	0.113	0.114
P	0.019	0.018
Mn	0.20	0.20
C	0.180	0.142
Fe	78.30	78.50
Total	84.532	84.454

The missing 15 per cent. is doubtless oxygen, as most of the silicon and some of the iron are present in the oxide state.

Resistivity.

Samples of vacuum-annealed scale were found to have an average resistivity of 53.1 microhms per cm.^{3} at 25° C. The individual values varied from 30 to 78. Previous tests on this material gave from 60 to 65 microhms, which is within the limits of the tests on the larger number of samples. These values are on the same order as those obtained from the steel itself.

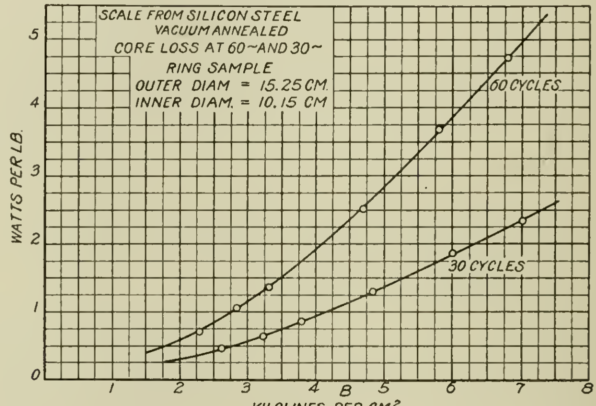
Temperature Coefficient.

This material was measured for temperature coefficient. The average figure given was 0.0059.

Core Loss.

Core-loss curves were made on the 15.25 cm. × 10.15 cm. sample at 60 cycles and 30 cycles from $B = 2500$ to $B = 7000$. Results are shown in Fig. 20. Data derived from these curves

FIG. 20.



are tabulated with the discussion of the hysteresis loss. A previous core-loss test at 60 cycles was found to agree with the 60-cycle curve in Fig. 20.

Hysteresis Loss.

The hysteresis loss at various densities was determined by the separation method. This was done by taking values from the core-loss curves at 60 cycles and 30 cycles and obtaining the loss per cycle as shown in Table XXI.

TABLE XXI.

Losses in Scale from Vacuum-annealed Sheet Steel.

	Total losses		Loss per cycle		Loss per cycle at 60 cycles	
B	60 cycles	30 cycles	60 cycles	30 cycles	Hyst.	Eddy
7500	5.52	2.58	0.0092	0.0860	0.0800	0.0120
6000	3.82	1.85	0.0636	0.0617	0.0598	0.0038
5000	2.80	1.38	0.0466	0.0460	0.0454	0.0012
4000	1.90	0.95	0.0317	0.0317	0.0317	
3000	1.10	0.56	0.0183	0.0187	0.0185	
2500	0.80	0.40	0.0133	0.0133	0.0133	

From the above table the hysteresis losses in ergs per cm.^{3} were calculated and the logarithms of the losses and of the inductions taken as shown in Table XXII.

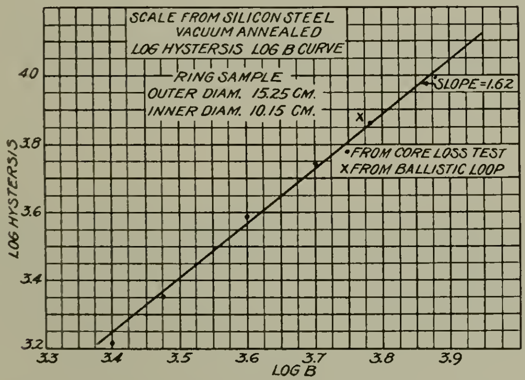
TABLE XXII.

Hysteresis Loss in Scale from Vacuum-annealed Sheet Steel.

B	Hyst. ergs per cm.³	Log B	Log hyst.	η (x = 1.6 assumed)
7500	9770	3.875	3.990	0.00616
6000	7310	3.778	3.864	0.00656
5000	5550	3.699	3.744	0.00670
4000	3870	3.602	3.588	0.00688
3000	2260	3.477	3.354	0.00618
2500	1625	3.398	3.211	0.00595
Average				0.00637

A plot of the log hysteresis – log B is shown in Fig. 21. Taking the five upper points of the curve, the slope given by the $\Sigma\Delta$ method is 1.62. Assuming $x = 1.6$, we obtain for η an average of 0.00637. For the five highest points average $\eta = 0.00646$. Here again we may note the insistence of the Steinmetz formula.

FIG. 21.



A loop was taken at B maximum = 5876, as shown in Fig. 22. The loss was found to be 7625 ergs per cm.³ Assuming $x = 1.6$, $\eta = 0.00711$. We may therefore assume the hysteresis of this material to be approximately $h = 0.007\ B^{1.6}$, or about 30 per cent. of that scale from mill-annealed material. That the hysteresis loss of silicon sheet steel may be lowered by means of vacuum anneal is a well-known fact.

Eddy-current Losses.

Table XXI shows eddy-current losses. These figures are not reliable and apply to a bulk of material rather than insulated sheets, and should not be considered as representing the material with any degree of accuracy.

FIG. 22.

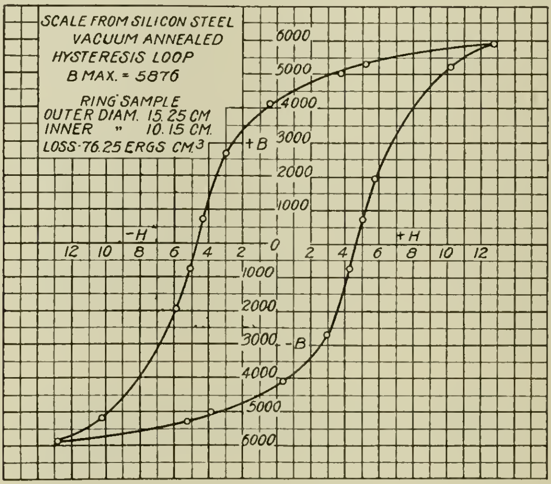
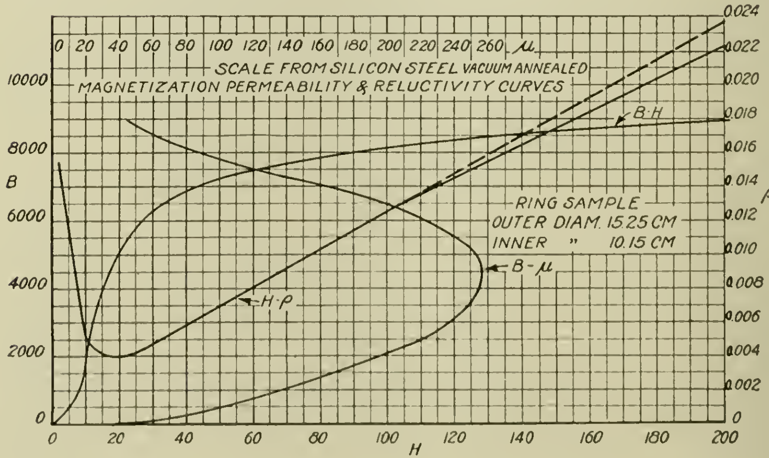


FIG. 23.



Magnetization, Permeability, and Reluctivity.

The two samples previously described were tested for magnetization curves. Results of the tests on the 15.25 cm. × 10.15 cm. ring are given in Table XXIII. The magnetization, permeability, and reluctivity curves are plotted on Fig. 23. The reluctivity curve is a straight line from $H = 30$ to $H = 90$, and also a straight line from $H = 90$ to $H = 200$, the limit of the test. The equations of the lines by the $\Sigma\Delta$ method are:

From $H = 30$ to $H = 90$:

$$\rho = 0.0014 + 0.00011\ H$$

Saturation $B = 9000$

From $H = 90$ on:

$$\rho = 0.0028 + 0.000097\ H$$

Saturation $B = 10{,}300$

The equations of the magnetization curves are therefore:

From $H = 30$ to $H = 90$:

$$B = \frac{H}{0.0014 + 0.00011\ H}$$

From $H = 90$ on:

$$B = \frac{H}{0.0028 + 0.000097\ H}$$

The maximum permeability of the sample is about 257 at $B = 4500$.

FIG. 24.

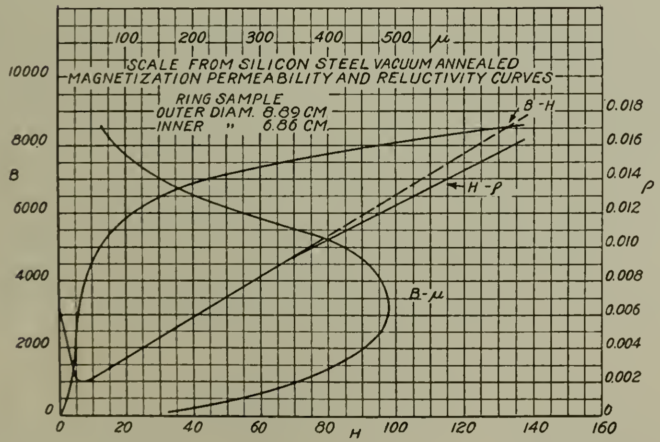


TABLE XXIII.

Magnetization Data of Scale from Vacuum-annealed Sheet Steel.

H	B	$\mu = B/H$	$\rho = H/B$
200	8980	44	0.0222
150	8640	57	0.0174
140	8530	60	0.0164
130	8430	64	0.0156
120	8375	69	0.0143
110	8250	74	0.0133
100	8170	81	0.0122
90	8010	88	0.0112
80	7920	98	0.0101
70	7708	109	0.0091
60	7499	124	0.0080
50	7245	144	0.0069
40	6876	171	0.0058
30	6337	210	0.0048
20	5060	253	0.0040
10	1919	192	0.0053
5	428	86	0.0116
3	210.2	70	0.0143
2	131.2	65.6	0.0152
1.5	55.3	36.9	0.0272
1.25	49.0	39.1	0.0255
1.0	37.2	37.2	0.0269
0.5	16.7	37.0	0.0269
0.3	10.8	35.9	0.0278

Tests were made on the 8.89 cm. × 6.86 cm. ring which showed better permeability than the previous results. The data are given in Table XXIV, and plotted in Fig. 24.

The equations of the reluctivity and magnetization were found as for the other samples. The results were as follows:

From $H = 10$ to $H = 70$:

$$\rho = 0.00101 + 0.000121\ H$$

Saturation $B = 8300$

$$B = \frac{H}{0.00101 + 0.000121\ H}$$

From $H = 70$ to $H = 137$. (Limit of test):

$$\rho = 0.00215 + 0.000103\ H$$

Saturation $B = 9700$

$$B = \frac{H}{0.00215 + 0.000103\ H}$$

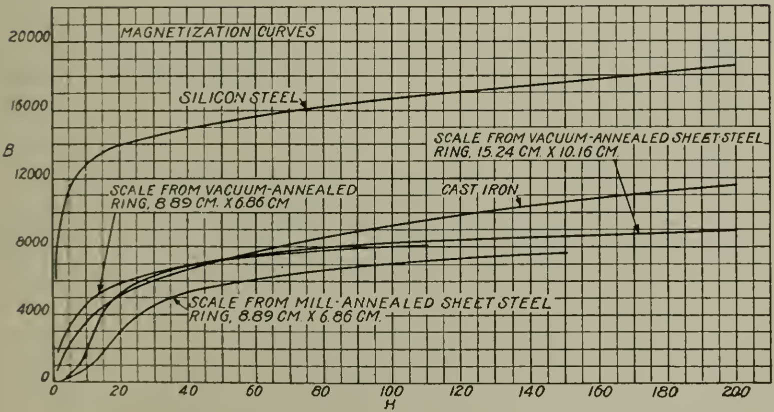
TABLE XXIV.

Magnetization Data of Scale from Vacuum-annealed Sheet Steel —Second Sample.

H	B	$\mu = B/H$	$\rho = H/B$
137	8560	61	0.0160
100	8074	81	0.0124
90	7908	88	0.0114
80	7749	96	0.0103
70	7529	110	0.0093
60	7374	124	0.0081
50	7124	144	0.0070
40	6829	170	0.0059
30	6440	214	0.0047
20	5880	294	0.0034
15	5405	359	0.0028
10	4570	457	0.0022
7.5	3662	487	0.0021
5.0	2385	476	0.0022
2.0	461.9	230	0.0043
1.5	325.5	216	0.0046
1.0	165.8	165	0.0060
0.5	80.7	160	0.0062

The maximum permeability of this sample is about 490 at $B = 3500$.

FIG. 25.



Skin Effect.

The skin effect of this material is more marked than for the mill-annealed product, because of its lower resistivity and high

permeability. Considering the permeability $\mu = 200$ and the conductivity 18,800, the penetration l_p at 10,000 cycles would be

$$l_p = \frac{3570}{\sqrt{18{,}800 \times 200 \times 10{,}000}} = 0.0194 \text{ cm.}$$

Assuming the thickness of the scales as 0.0056 cm., l_o, or ½ of the thickness, is 0.0028. Therefore there is no appreciable skin effect at 10,000 cycles. The maximum allowable thickness of scale which has no appreciable skin effect at 10,000 cycles would be 0.0388 cm. (0.015 inch). The maximum frequency at which no appreciable skin effect would be in evidence would be found by letting $l_p = 0.0028$ and solving for f, which gives 480,000 cycles.

Considering the magnetization curves, the values of η, and the resistivity, we find scale has those properties on much the same order as found for cast iron. Magnetization curves of silicon steel, cast iron, and the samples of scale are shown on Fig. 25.

On the Cooling of Cylinders in a Stream of Air. P. J. A. HUGHES. (*Philosophical Magazine,* vol. 31, No. 182, February, 1916.)—The interchange of heat between a solid and a moving stream of gas is a subject of considerable technical importance. A considerable amount of work has been done on the cooling of thin wires in a current of air, mainly with the object of constructing instruments for the measurement of air-velocity. These experiments have shown that the heat lost by the wire is proportional to the difference of temperature and to the square-root of the velocity. There are, however, no data available relating to the convection of heat from bodies of large diameters. The experiments described in this paper were undertaken with a view of throwing some light on the problem of convection in these cases.

The measurements were carried out on a series of copper tubes all of the same length but with external diameters ranging from 0.433 cm. to 5.06 cm. These tubes, of about a metre in length, were placed vertically in a wind-channel, and were heated by steam. After a steady temperature was attained, the weight of the water which condensed in the cylinder in a given time measured the heat which it lost through convection and radiation.

An analysis of the results shows that the heat-loss is proportional to the n^{th} power of the velocity. The value of n increases from 0.5 for cylinders of very small diameter to 1 for cylinders of large diameter, thus bringing into agreement the results of other experimenters on large bodies and on wires. Experiments on tubes of stream-line section showed losses slightly greater than those from a circular tube of the same total area, but much greater than from a circular tube of the same width or the same air resistance.

COAL-GAS RESIDUALS AND THEIR APPLICATION.*

BY

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Member of the Institute.

The destructive distillation of coal, as practised to-day, may be divided into two classes, the first being that practised in gas works, the second being the one practised by the coke oven operator. The latter method of distillation, or carbonization, may also be subdivided into two classes, or distillation with by-product recovery, and bee-hive oven distillation; as the latter yields no other product than coke, it will not be given any further consideration.

These two classes of distillation, or carbonization, lead to two very different methods of operation; the object of the gas works operator is to produce a maximum yield of gas possessing certain required qualities, such as candle-power and thermal value, with the recovery of certain by-products, while the object of the coke oven operator is to produce a maximum of low-volatile coke, the recovery of by-products, in some instances, being entirely neglected.

The quantity of gas produced, as well as the production of coke and other by-products, is entirely dependent upon the character of the coal distilled, as well as on the character of the carbonizing plant. Gas intended for cooking or illuminating purposes must possess certain characteristics, and must consequently be purified, as the crude gas contains substances which are of a harmful character, and, if retained in the gas, these substances would be liberated during combustion; but these substances all possess a commercial value, and, with the exception of coke and retort graphite, the by-products secured from a gas works are therefore due to the necessity of cleaning the gas before it can be used for domestic purposes.

The principal by-products consist of coke, retort graphite, tar,

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 6, 1916.

naphthalene, ammonia, cyanogen, and sulphur. Owing to the necessity, in many cases, of selling domestic gas on a candle-power basis, it is not advisable to remove such valuable products as benzol and toluol from the gas works product, and, as a rule, these constituents must therefore be sought in the products from the coke oven.

The appended diagram, adapted from one prepared by W. J. Butterfield, approximates the average yield of primary products, the return of secondary products secured from the primary, as well as the ultimate yield of some of the more important subsequent products, the amounts secured being based on the distillation of 100 tons of coal in gas works practice.

While this diagram gives the total amount of coke produced as 70 tons per 100 tons of coal carbonized, the amount of coke of salable size will hardly average more than 50 tons, and often less, due to the amount used as fuel in the producers which supply the heat required for distillation, and to the amount of breeze produced by handling. In Germany this coke breeze is worked up into briquettes, but little has been done in this particular in this country, probably due to our still illimitable supply of coal, and to our negligence in the conservation of our resources.

The salable coke produced in coke ovens amounts to from 60 to 65 per cent. of the weight of coal carbonized, this latter coke being distinguishable from gas works coke in that it is better adapted for metallurgical purposes.

The amount of graphite produced in the retort is dependent upon the type of retort used, as well as on the heat of carbonization employed, also on the character of the coal distilled; this graphite has quite some commercial value.

The moment the gas is released from the coal, and when it is subjected to cooling, it begins to condense and to drop various compounds of a hydrocarbon nature, these compounds being deposited in conjunction with an aqueous solution of ammonia salts combined with dust and soot; these hydrocarbon substances, together with the dust and soot, form tar.

After the gas has been subjected to this process of cooling, or after the tar and a portion of the ammonia compounds have been removed, the gas is usually subjected to a washing process for the removal of the remaining ammonia, or the ammonia may be directly absorbed by passing the gas through a sulphuric acid bath

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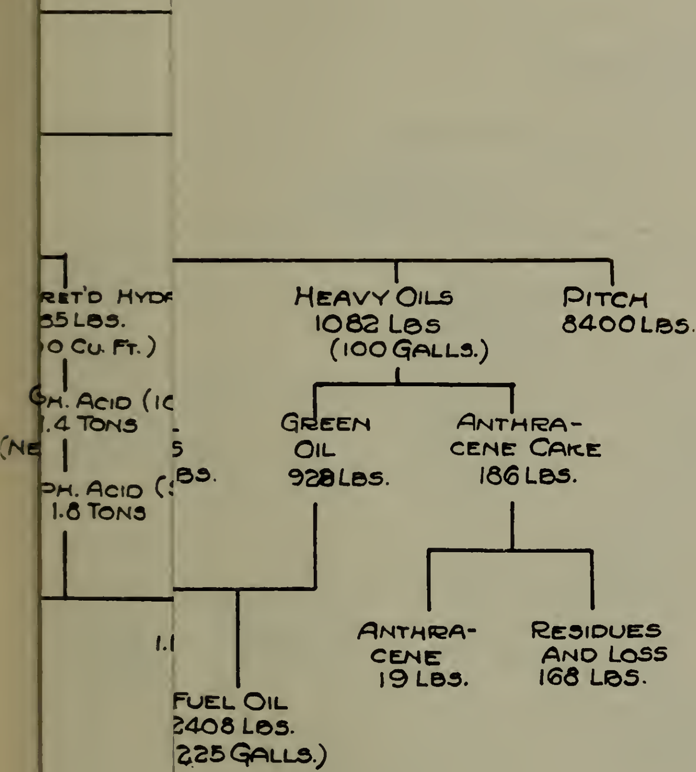
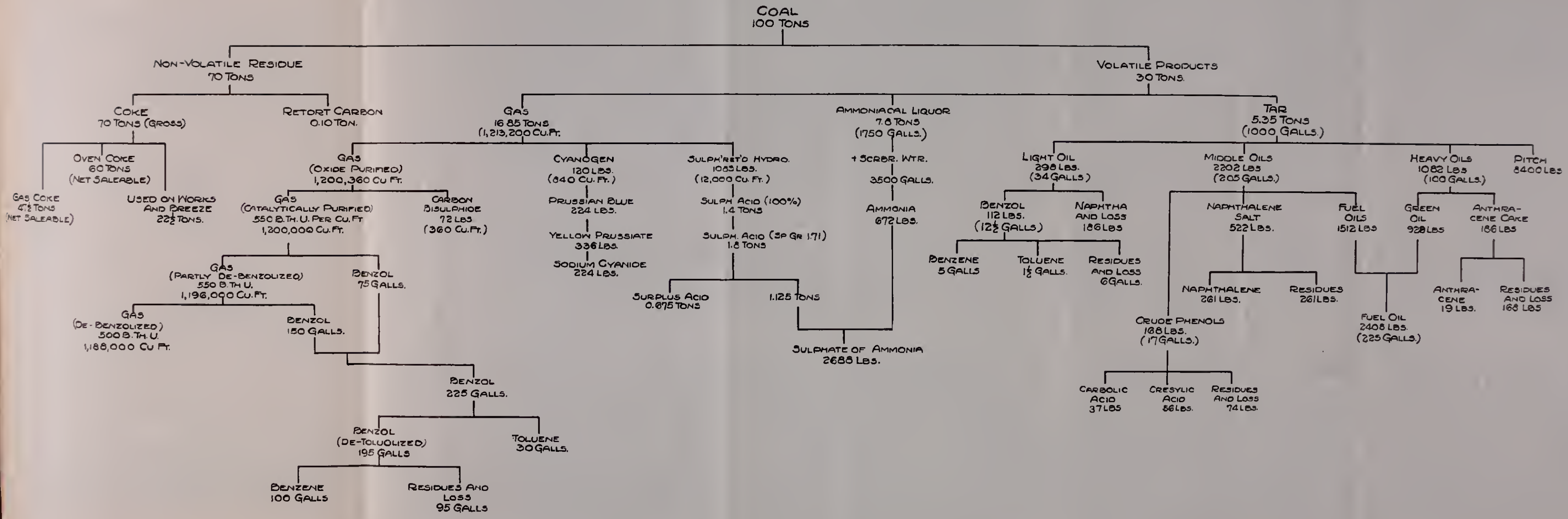


Heavy Oils
1082 Lbs
(100 Galls.)
Pitch
8400 Lbs.
Green
Oil
928 Lbs.
Anthra-
cene Cake
186 Lbs.
Anthra-
cene
19 Lbs.
Residues
And Loss
168 Lbs.
Fuel Oil
2408 Lbs.
(225 Galls.)
1.8 Tons
.4 Tons

Products from the Distillation of 100 tons of Bituminous Coal.



The cyanogen in the gas may be removed either before or after the removal of the ammonia, the gas, in the first case, being washed with an iron solution with the consequent formation of ammonium ferrous-ferrocyanide, this being an insoluble product, while in the second case the gas is washed with a solution of hydrated lime and iron, this latter product being a soluble one; these products are generally converted into potassium ferrocyanide, commonly known as yellow prussiate of potash, or into sodium ferrocyanide. At present the removal of cyanogen from coal gas is a very profitable investment, but, besides this, its removal is of distinct advantage in operation, as the presence of cyanogen has a very deleterious effect on all steel work, and especially on gas-holder sheets.

The sulphur compounds are usually removed in the purifiers, but a portion is absorbed during the process of washing and condensing: this constituent, principally in the form of hydrogen sulphide, is usually absorbed by oxide of iron, but little lime being used for this purpose to-day. The sulphur thus absorbed is removed from the oxide of iron and converted into sulphuric acid. Unless special requirements call for the removal of carbon bisulphide it is retained in the gas, as its removal entails quite some difficulties and its economy is open to question.

The apparatus usually employed in gas works practice is so constructed as to remove not only the so-called impurities, but also valuable by-products by condensation and absorption, the removal by condensation being due to the fact that the coal is distilled at very high temperatures, thus causing the formation of various gaseous products which do not remain in the gaseous state at ordinary temperatures, and which are therefore readily removed during the process of cooling.

This short explanation of the method of operation and the statement of the nature of the by-products to be expected enables us to give a more detailed description of the products and their uses.

Coke is the first by-product obtained through the dry distillation of coal, and it is the residue left in the retort or oven chamber after the volatile products have been driven off. The composition of the coke is, of course, dependent upon the character of the coal carbonized; it is hard and brittle, and varies in color from very dark to silver gray, being composed of highly complex com-

pounds of carbon, hydrogen, oxygen, nitrogen, and sulphur. The porosity or density of coke is dependent upon the type of retort used for distilling and upon the method of quenching and handling the coke after it has been ejected from the retort; in gas works practice vertical retorts produce a coke of maximum density, due to the fact that the weight of the coke itself causes a sintering of the coke particles. Gas works coke is generally used for domestic purposes, the metallurgist depending in most cases on the product received from the coke oven.

The late Prof. Vivian B. Lewes, of England, said: "Among the factors that lead to the commercial supremacy of a country, by far the most important is the command of fuel or other source of power; and England's position in the past has been governed largely by her coal fields, which in little more than a century raised her to the forefront as a commercial power. The very abundance of our coal supplies was a source of weakness, as it led to outrageous waste, polluted our atmosphere to a criminal extent, and so encouraged uneconomical methods of using it as seriously to deplete our available stock, the result of which has been the increase in price during the last few years, and the certainty that the future will see further advances but no fall to the old rates. The day of cheap coal has gone, never to return."

If this statement is true for England, how much more so is it applicable to our own conditions, where so much remains to be done in conserving our fuel beds, and this conservation can be greatly aided by a concerted effort to educate the user in the benefits to be derived from the burning of coke; but, here again, we find that in the manufacture of metallurgical coke the warning has not been heeded, and this industry in many instances exhibits a prolific waste which is almost criminal. The change from the bee-hive to the by-product oven is very slow, but it is progressing; we find that in 1893 the bee-hive ovens produced 9,464,730 short tons of coke, the by-product ovens producing only 12,850 tons during this same period; in 1901 the product was: bee-hive ovens 20,615,983 tons, by-product ovens 1,179,900 tons; in 1910, bee-hive ovens 34,570,076 tons, by-product ovens 7,138,-734 tons; and in 1913 the bee-hive oven product amounted to 33,584,830 tons, while that from the by-product ovens was 12,-714,700 tons. It is true that the total consumption of coke has increased, but while that produced by the bee-hive ovens in 1893

amounted to 99.99 per cent. of the total, this was decreased to 94.59 per cent. in 1901, to 82.88 per cent. in 1910, and to 72.54 per cent. in 1913.

A series of tests made by the American Radiator Company to determine the efficiency of domestic fuels showed that gas coke of nut size led the list with an efficiency of 78.7 per cent., followed by gas coke of egg size with 75.43 per cent.; Pittsburgh coke with 71.40 per cent.; anthracite coal with 66.30 per cent., and Pocahontas coal with 66.10 per cent. It was also shown that in ease of kindling Pocahontas coal stood first, but gas coke of nut size was a close second, followed by gas coke of egg size, Pittsburgh coke, and anthracite coal last. Gas coke burns with an even, smokeless fire, it is easily controlled and clean to handle; it is also probably the most economical fuel on the market, and there is no reason why it should not displace many forms of domestic fuel now in use, thus greatly assisting in conserving our coal supply and adding benzol and toluol, with their subsequent products, to our source of national wealth.

Retort graphite is produced by the decomposition of the hydrocarbons in the gas, these latter constituents having been deposited on the walls of the retort. Owing to its poor heat-conducting qualities, it must be removed periodically from the inside of the retorts, clay retorts requiring more frequent cleaning periods than do those made of silica.

This graphite has found its most important application in the production of carbon electrodes, the raw graphite being thoroughly cleaned, crushed into a powder, and then formed into a plastic mass by the admixture of coal-tar and lamp-black; this mass is formed into rods by passing it through a hydraulic press.

The rod thus formed is then baked in a kiln, where the coal-tar is decomposed by heat, producing graphitic carbon, which combines with the retort graphite and forms a hard but brittle mass.

Tar is chiefly removed from the gas by progressive condensation, and, when removed in this manner, is accompanied by so-called gas liquor, or ammonia liquor, these two liquids being later separated by virtue of their difference in specific gravity. The gas, after this treatment, still contains a certain amount of tar in the shape of a fog or mist, and this is usually removed by friction in some sort of mechanical extractor.

These accepted methods of tar removal are now being re-

placed by others of greater value, such as the electric de-tarring system in which the gas is sent through an electric field, the action of which is to cause the tar to coalesce and drop out of the gas, and the system which embraces progressive washing combined with progressive cooling, in which, due to the fact that the gas is not cooled below the point where any volatile hydrocarbons are condensed or absorbed by the effluent, the tar is fractionated into pitch, heavy oils, and middle or light oils, without the usual interposition of a tar still.

Tar is one of the most valuable of all coal-gas residuals, and while, in this country, owing to economic conditions, it has found quite some extended use in its original form, it finds its greatest value in its application in the arts; the distillation of tar at certain temperatures produces a water-like oil, which in turn forms the base of so many of the beautiful coal-tar colors so much in demand at present. Carbolic acid, naphthalene, anthracene, and benzol are also produced by this distilling process, and each of these constituents in turn produces a long series of other products.

Naphthalene is one of the gas constituents which accounts for a great deal of the trouble experienced in present-day methods of carbonization, but its removal can be accomplished by washing the gas with a suitable oil, such as anthracene or creosote oil, or water gas tar, the resultant emulsion being gradually cooled, thus causing a separation of the naphthalene crystals.

The formation of naphthalene is probably due to the high heats employed in present-day carbonization, it being a generally-accepted fact that this formation is brought about by a partial decomposition of the tar in the gas. Fortunately, the greater portion of the naphthalene produced goes over into the tar effluent and is thus removed with the latter, as its excessive presence in the apparatus and gas mains usually causes a stoppage. Naphthalene is also due to the character of the coal used, and upon the time of contact between the gas and the hot coke and hot retort walls. Besides other domestic uses, naphthalene is of great importance at present in the production of dyes.

Cyanogen is a carbon-nitrogen compound, and it is probably produced during the period of carbonization in the form of hydrocyanic acid by the decomposition of some of the ammonia due to the contact of the gas with the hot coke and the hot retort walls, this statement being substantiated by the fact that the

quantity of cyanogen produced by the carbonization of any particular coal bears a certain relation to the amount of nitrogen (ammonia-producing agent) in the coal.

In its gaseous form cyanogen is colorless and very poisonous; in combination with potassium it forms potassium cyanide, this latter compound having found its largest application in the cyanide process of gold extraction, which process depends upon the solubility of gold in a dilute solution of potassium cyanide in the presence of air or some other oxidizing agent; this process is best adapted for use with free-milling ores after the greater portion of the gold has been removed by amalgamation, thus recovering such portions as were not taken up by the amalgam, the gold being later usually separated from the cyanide solution by an electric or metallic precipitation process.

Potassium ferrocyanide is the base of a great many cyanogen products, one of the principal products being Prussian blue; this coloring matter is obtained by mixing the potassium ferrocyanide with a solution of ferrous sulphate, a grayish-white precipitate of ferropotassic ferrocyanide resulting, the mother liquor, which contains potassium sulphate, being removed from the precipitate by decantation. After this precipitate has been allowed to settle, it is washed with a large amount of water and then oxidized, this oxidation giving it the beautiful blue color required in the dyeing industry.

In one process covering the removal of cyanogen from gas, iron sulphate, commonly known as copperas, and ammonia are used as the two reagents necessary to combine with the cyanogen, and a certain portion of the ammonia thus removed from the gas remains in the cyanide cake, the final resulting compound being ammonium ferrous-ferrocyanide. This process, therefore, requires that the cyanogen be removed before the ammonia has been extracted, but in another process the ammonia is replaced by milk of lime, and consequently follows behind the ammonia extraction process, the final product being calcium ferrocyanide.

In another process used in England the cyanogen is removed from the gas by washing the latter with a solution of soda and ferrous carbonate, the resultant liquor being deprived of its ammonia by evaporation. This liquor is then pumped through a press where the insoluble matter is removed, the cleared solution being then crystallized, giving sodium ferrocyanide, or prussiate

of soda. This latter product is washed for purification and then recrystallized.

Ammonia is a nitrogen-hydrogen compound, and, besides being a source of great revenue to the coal-gas producer, its removal from the gas is necessary for both practical and hygienic reasons; its presence in the gas exercises a destructive influence on the brass and copper work of meters and gas fittings, and when burned in conjunction with gas it gives off noxious fumes of oxides of nitrogen.

The usual method employed for the removal of ammonia depends upon the solubility of ammonia in water, as at ordinary temperatures water can absorb about 708 times its volume of ammonia gas. Raw ammonia liquor from a gas works usually contains from one to two per cent. of ammonia, and, owing to the excessive cost of transporting this weak liquor, it is usually worked up into concentrated liquor, aqua ammonia, or ammonium sulphate.

Concentrated ammonia is a product obtained by distillation of the raw liquor with lime, and absorption, in water, of the ammonia evolved. It is used in the production of other ammonia compounds.

Aqua ammonia is a solution of ammonia in distilled water, a great deal of it, in a dilute solution, being used for cleansing purposes.

Ammonium sulphate is produced by distilling the liquor and absorbing the ammonia vapors in a sulphuric acid bath, thus forming the sulphate crystals; or it may be made by passing the gas, after the tar has been removed, directly through the acid bath, this being the so-called direct process. The only really direct process, however, is the one in which the ammonia in the gas is combined directly with the sulphur radical, the latter also existing in the gas, this compound being later oxidized. This process requires that the gas be washed with ammonium polythionate, the latter absorbing both ammonia and hydrogen sulphide, the resultant liquor being oxidized or regenerated by means of sulphur dioxide gas, and after the liquor contains about 35 to 40 per cent. of ammonium sulphate in solution it is boiled, resulting in the breaking down of the polythionates with the consequent precipitation of the sulphur; this sulphur is returned to the sulphur stoves for the further production of sulphur dioxide, while the cleared liquor is evaporated to crystallization, this

method of procedure therefore requiring no sulphuric acid for the production of the salts, but finding all of the necessary reagents in the gas itself. Sulphate finds its greatest use in the manufacture of fertilizer, it being the active nitrogen-carrying agent in this product; it is also used for the production of other ammonia compounds.

Ammonium chloride, commonly termed sal ammoniac, is produced by using hydrochloric acid as an absorbing agent, followed by evaporation and crystallization. Ammonium sulphate is the principal source of sal ammoniac production in this country, the sulphate being heated in conjunction with common salt for its formation. Sal ammoniac is used as an agent in the galvanizing process, for soldering, and as an agent in electric batteries.

Liquid anhydrous ammonia is produced by freeing the ammonia gas of all moisture and impurities, after which it is liquefied under pressure; this product is used in the production of low temperatures by the absorption of heat, as in refrigeration.

Ammonium carbonate is produced by heating ammonium sulphate in conjunction with calcium carbonate, and it finds its greatest application in the scouring of wool.

Ammonium nitrate is produced by neutralizing nitric acid with ammonia, and it is used in the manufacture of explosives.

There are many other ammonia compounds, but the ones here cited are the principal products, and they can all be prepared from ammonium sulphate, thus making this latter compound one of the principal by-products of coal distillation.

Benzol and its homologues are obtained during the process of tar distillation and from the products due to coke oven distillation, they being secured in the latter case by washing the gas with a suitable oil, the resultant product being purified by repeated distillation and washing, thus separating it into benzol, toluol, xylol, and solvent naphtha; the greatest usefulness of these products is in the production of dyes, explosives, artificial perfumes, and pharmaceutic compounds.

COAL-TAR AND BENZOL PRODUCTS.

A large number of our industries are dependent upon the use of coal-gas by-products for their successful operation, as is witnessed by the following statement, taken from the census of 1909. The

principal industries dependent upon coal-tar products, with the number of employees, capital invested, and annual value of product, are:

Industry	Employees	Capital	Product
Textile	916,000	$1,841,000,000	$1,685,000,000
Leather	62,000	323,000,000	328,000,000
Paper	81,000	400,000,000	260,000,000
Paints and colors	30,000	250,000,000	

Thus we find a total of 1,089,000 persons employed in these four industries, with a capital investment of $2,814,000,000, and an annual product for the first three representing $2,273,000,000 in value. Since the 1909 census these industries have all increased their production, and, when taken in conjunction with other manufacturers, such as the producers of shoe dressings, writing and printing inks, etc., it is perhaps safe to estimate that at present fully 2,000,000 persons find employment in industries which are dependent upon dyestuffs for their success.

Artificial dyestuffs, produced from the by-products of coal distillation, have practically displaced those formerly used, such as natural indigo, cochineal, fustic, madder, and many others, and this is properly so, because the artificial material is easier applied, has a greater brilliancy of color, and can be secured in a great variety of shades; but, unfortunately, our American industries have always depended on Europe to supply the necessary material. Statistics teach us that 80 per cent. of our coal-tar dye requirements are imported from Europe, principally from Germany, the other 20 per cent. being produced by American manufacturers; but here again we find that we must turn to Europe for our supply of the greater portion of the necessary intermediates, or raw product, before we can produce this 20 per cent. of coloring matter.

The present war soon brought about an acute situation among our manufacturers, as the stock on hand was soon depleted, and a replenishment became almost impossible. The seriousness of this situation can readily be recognized when I mention that "sulphur black" increased in price from 20 cents to as much as $3 per pound; indigo from 15 cents to $1 per pound; paranitraline from 15 cents to $1.75; aniline oil from 10 cents to $1.75; betanaphthol from 12 cents to $1.50; and so on through the list. As regards the raw or primary material, I might mention that the

price of benzol has increased from 20 cents to as much as $1.20 per gallon, with about 70 cents as a contract price, while toluol has increased from 25 cents to about $6 per gallon, with a contract price of about $4.25.

These conditions certainly compel us to turn seriously towards our own supply of tar and benzol and cause us to question ourselves as to our ability to do that which we have permitted others to do for us. Several American manufacturers have gone ahead vigorously in an attempt to supply our domestic needs, and credit for stepping into this breach must be accorded such firms as the Shoellkopf Aniline and Chemical Works, Inc., Buffalo, N. Y.; The Hudson River Aniline Color Works, Albany, N. Y.; W. Beckers Aniline and Chemical Works, Brooklyn, N. Y.; Central Dyestuff and Chemical Company, Newark, N. J.; and Heller and Merz Company, Newark, N. J.

Other concerns have taken up the manufacture of intermediate products from our raw material, and, while all of these manufacturers are being supported by the allied industries today, the question as to their future is still an open one, and reference to this will be made later.

We have the necessary raw material, tar and benzol, on hand, and a lack of these products will soon bring about their further recovery if the situation should demand it, as the greater amount of coal carbonized for the production of coke in America, as previously stated, is still produced in the wasteful bee-hive oven. Economic and commercial conditions have prevented the development of the dye and other allied industries in this country, and consequently our manufacturers have in the past diverted their raw material in great measure into the production of tar oils and pitches.

Tar is a very complex substance, and it has been estimated that it consists of a mixture in excess of two hundred chemical compounds. The constituents of tar are usually divided into three classes, the first being the hydrocarbons, the second the phenols, and the third the nitrogenous compounds, these classifications being made in accordance with the chemical reactions of the compound in question. The hydrocarbons, as can be seen from the name, are composed of hydrogen and carbon, and they are termed chemically indifferent substances because they exhibit neither alkaline nor acid properties. The hydrocarbon

compounds, of which benzene, toluene, xylene, naphthalene, and anthracene are the most valuable, form the principal portion of coal-tar. The phenols, or the second class of constituents, consist of oxygenated bodies of carbon, hydrogen, and oxygen, being known as the "tar acids." Owing to their weakly acid condition, they can be dissolved in caustic alkali solutions, but not in dilute acids. The most important members of the phenol group are carbolic acid and cresol. In the third class we find compounds composed of carbon, hydrogen, and nitrogen, these compounds being of a basic nature and soluble in acids.

The distillation of coal-tar thus serves to produce a number of fractions, and these fractions in turn form the base for manufacturing various other important products. Distillation of the average coal-tar usually gives us four fractions, the first being "light oil," which comes over at a temperature of between 70° and 160° C. (158° and 320° F.); the second is a "middle" or "dead oil," coming over between 160° and 230° C. (320° and 446° F.); the third is a "heavy oil," including anthracene oil, and it comes over at between 230° and 360° C. (446° and 680° F.), while the fourth is pitch, or the residue above 360° C.

The first fraction, or "light oil," produces such intermediate products as benzene, toluene, xylene, and phenol (carbolic acid), while the crude commercial products are benzol and solvent naphtha; the intermediate chemical products are nitrobenzene, aniline salts and oils, and carbolic acid, while the refined chemical products are the nitrotoluenes, diphenylamine, dyes, hydroquinone, and various medicines and drugs.

The "middle oil" gives us phenol, cresols, naphthalene, and heavy hydrocarbons as an intermediate product, the crude commercial products being creosote oil, lamp-black, and various disinfectants. The intermediate chemical products are carbolic acid, picric acid, phthalic acid, naphthols, naphthylamine, and salicylic acid, while the refined chemical products consist of picric acid, the picrates, and several other nitro-compounds used in the manufacture of explosives; naphthol dyes, colors, indigo, and refined carbolic acid.

The "heavy oils" produce cresols, naphthalene, anthracene, heavy hydrocarbons, and quinoline bases; the crude commercial products consist of oils used in road making, lamp-black, creosote oil, roofing and paving tars. The intermediate chemical prod-

ucts consist of anthraquinone and alizarin, while the alizarin dyes are known as the refined chemical products.

The fourth fraction consists of soft and hard pitch, a large portion of which is used in the manufacture of protective paints.

The manufacture of aniline dyes necessitates quite a number of very complicated chemical combinations, and the chief sources of this product are to be found in benzene, toluene, and phenol, or in the nitro-substitution products of these compounds; this material is used in conjunction with nitric, sulphuric, and acetic acids, alcohol, sodium nitrite, caustic alkalies, zinc dust, bromine, and chlorine.

The naphthol dyes are produced from phthalic acid, the naphthols and naphthylamines, etc., these being intermediate products derived from naphthalene. The eosin dyes are due to benzene and naphthalene through the medium of resorcin and phthalic acid; indigo is also a naphthalene product.

Anthracene is converted into anthraquinone by oxidation, and this in turn gives us the hydroxyanthraquinones and such derivatives as the alizarins, purpurin, etc., all of which are used in the production of alizarin dyes.

Carbolic acid, or pure phenol, is, as stated before, obtained from both the light and middle oils, and it can also be made synthetically from benzene; it is used as a drug as well as an antiseptic, and it occupies a very important rôle in the manufacture of picric acid and some of the dyes.

The manufacture of synthetic phenol, using benzol as a base, was not encouraged or practised in this country before the present war, and consequently little attention has been paid to this branch of conservation, and it may therefore be interesting to give a short explanation of its manufacture.

The benzol stripped from the gas, or secured as a distillation product from tar, is first sulphonated by mixing about 2.7 parts of 98 per cent. sulphuric acid with one part of benzol in a cast-iron vessel having a capacity of approximately 400 gallons, this vessel being supplied with means for both heating and cooling the liquid, the escaping matter passing through a reflux cooler, about 150 pounds of benzol being treated at a time. This mixing vessel is provided with an agitating device, and the agitator is set in motion as soon as the benzol is admitted, the sulphuric acid being in the mixer before the benzol is added.

As soon as these two liquids mix, the temperature rises to between 62° and 68° C. (144° and 154° F.), and when the chemical reaction produces no further increase, external heat is applied to a point corresponding to the boiling-point of benzol, about 88° C., or 190° F. This sulphonating process is usually completed in from seven to eight hours.

The sulphonic acid produced as per the above is run into a neutralizing vessel, the latter having a lead lining, where it is first neutralized with milk of lime, and then treated with waste calcium carbonate; this treatment is liable to thicken the liquor, and, if so, some water is added to thin it out, after which the mixture is subjected to a boiling temperature for about one-half hour, steam being used for this purpose. After the steam has been turned off, a volume of water amounting to 150 per cent. of the volume of the original sulphonation mixture is added, this being necessary in order to prepare the calcium sulphate for washing and filtration.

This mixture is now forced through a filter press, where it is also washed with water, the latter amounting to about 50 per cent. of the volume of the mixture. The resultant product is a calcium benzene-sulphonate mixture, and this is now treated with solid sodium carbonate in order that it may be converted into a sodium salt, while the precipitated calcium carbonate is used in neutralizing the sulphonation mixture. The sodium benzene-sulphonate solution is now evaporated, the resultant salt being dried and pulverized, this dried product being placed in a fusion vessel where about 500 pounds of caustic soda are melted with about 50 pounds of water for every 600 pounds of the dry sodium benzene sulphonate, the caustic soda and water being heated to about 270° C. (518° F.) before the sodium benzene-sulphonate is added; heating is continued up to about 315° C. (600° F.), a still further, but slight, rise in temperature taking place after the heat is turned off, the operation being considered complete when all of the sodium salt has been dissolved and the mixture is thin.

The resultant product is now removed from the fusion vessel by means of ladles and placed on shallow trays, where it is allowed to cool, after which it is crushed and dissolved in water, being then treated with sulphuric acid until sulphurous acid begins to go off, this sulphurous acid being finally blown out of the vessel with an air blast, thus separating the crude phenol from the mix-

ture. the latter being then distilled, and the phenol crystals recovered by crystallization. The phenol crystals obtained in this manner usually contain some sulphur compounds which produce disagreeable odors, but this can be removed by distilling the crude product in conjunction with animal charcoal.

The light oil fraction is also responsible for the production of photographic developers as well as of such drugs as phenacetin, acetanilide, antipyrine, aspirin, saccharine, and phenolphthalein.

The synthetic production of many perfumes also owes its existence to coal-gas tar, and it is almost impossible for the layman to differentiate between the natural products and the synthetic substitutes.

Modern coal-tar dye classification divides this product into eight classes, or

1. Acid dyes;
2. Tannin dyes;
3. Dye salts;
4. Sulphur dyes;
5. Vat dyes;
6. Mordant dyes;
7. Developing dyes;
8. Albumin dyes;

and they may be described as follows:

1. The greater portion of the acid dyes consist of sodium salts of sulphonic acids or organic acids or nitro acids, and they are represented by the azo dyes, the eosines, and picric acid. They are used principally for dyeing wool and silk, this material being dyed directly with the aid of an acid or an acid salt in the bath. Cotton is not dyed by these compounds.

2. The tannin dyes are also classed as basic dyes, consisting in large part of hydrochloric acid salts of color bases; if cotton is first treated with tannin we find that it is easily dyed, but we find that wool and silk can be dyed directly without the aid of this intermediate treatment.

3. The dye salts receive their names from the neutral or alkaline salts which are dissolved in the dye solution; they are also termed direct-cotton dyes and substantive cotton dyes, consisting usually of sodium salts of sulphonic or organic acids, the cotton fibre taking them up in this state. The dye-bath also receives some common salt or Glauber's salt.

4. The sulphur dyes consist of a class of colors which are very popular owing to their cheapness and fast qualities. The bath is made alkaline with the soluble sulphides, the color being later developed by oxidation after the cotton material has been removed from the bath.

5. The vat dyes show but little attraction for the common fibres, and they are fixed on the material by reducing them to their leuco compounds in the vat. The material to be dyed is immersed in this reduced dye and thus becomes saturated with it, after which it is exposed to the air, where the color is developed by oxidation.

6. The mordant dyes are of a weak acid character. In order to cause their retention by the fibre, they must be converted into color lakes by means of a mordant, with which the fabric is impregnated prior to treatment in the dye bath. The color known as Turkey red is an example of this class of dye, being made from alizarin, which is yellow and is almost insoluble; the cotton fabric to be dyed is first treated with aluminum salts and Turkey red oil, then is boiled in the alizarin, after which it is treated with calcium salt, the Turkey red color resulting.

7. The developing dyes, owing to their insolubility, cannot be applied directly to the fabric to be dyed, but they are produced upon the fabric itself by first saturating the latter with one soluble component and then immersing it in a second bath of another soluble component, these two components uniting and forming an insoluble dyestuff.

8. The albumin dyes will not adhere of themselves, and they require that the fabric be first treated with some strongly adhesive substance, the principal substance used for this purpose being albumin.

This classification of dyes is only mentioned in order to make somewhat clearer the complex nature of the dyer's art.

The coal-tar dyestuffs found their origin in England, where, in 1856, W. H. Perkin discovered mauve, a sort of violet; this was an accidental discovery, as Perkin was seeking something entirely different, but his chemical ability, combined with a keen business sense, caused him to persevere in this line of chemical research, and he lived long enough to find his crude beginning develop into an immense business which utilized a material, coal-tar, that had previously been considered worthless. The discovery of mauve was soon followed by magenta and fuchsin, while the

soluble blues were discovered in 1862, Hofmann's violet and Bismarck brown in 1863, naphthol or Martius yellow in 1864, and the nigrosines in 1867.

These beginnings soon drew the attention of the Germans to this new industry, and, recognizing the immense possibilities in its development, they very quickly applied their usual patient perseverance and intelligent research to the advancement of this new art; this resulted in the production of orange, red, malachite green, chrysodine, scarlet, metanil yellow, methylene blue, and the eosines between 1875 and 1878; auramine was first produced in 1883; tartarzine and benzopurpurine in 1884; Congo red, benzoazurine, and naphthol black in 1885; diamine red in 1886, and rhodamine in 1887. The early nineties saw the discovery of direct black for dyeing cotton, and acid and chrome black for dyeing wool. It was von Bayer who first succeeded in producing indigo, but many years of patient labor were required before a practical synthetic process permitted of placing this important dyestuff on the market in a commercial sense.

From the latest reports, I learn that the Dow Chemical Company, of Midland, Mich., is erecting, or has erected, a plant for the production of 5000 pounds of 20 per cent. indigo paste per day.

Realizing that industrial progress in this line meant commercial supremacy, the Germans quickly learned that success meant patient scientific research, combined with an adequate supply of raw material, with the result that by-product coke ovens were soon established in the immediate vicinity of their blast furnaces, where the distillation of the coal for the production of the necessary metallurgical coke soon supplied them with all of the by-products required in the development of this new art, an example which we might have followed in the past with great profit, and with relief of mind at present.

The cost of producing dyes in this country is said to be 44 per cent. greater than in Germany, as it is estimated that the cost of a plant capable of producing 3,000,000 pounds of dyestuffs per year would be $104,000 in the United States and $70,000 in Germany, while the labor required would amount to $116,236 in the United States and $61,493 in Germany. The cost of material would be $443,000 in the United States and $317,000 in Germany. These comparative figures show a vast difference in favor of Germany, and the successful establishment of this industry in our

country would require that protection in some form be given the American manufacturer in order to make up this discrepancy.

The discrepancy is even greater than these figures would seem to indicate, because the German manufacturer has been in the habit of selling us his surplus production, and that at a figure lower than the one paid by the domestic consumer. The establishment of this industry in the United States means opposition to the preëminent position of the Germans, whose success is based on a solid foundation of 30 years' standing, and which, therefore, becomes a standing challenge to our chemists and capitalists. We have the necessary raw material, and we possess constructive engineering ability of a character which can supply all of the needful apparatus, but, with all this, an almost unlimited capital and patience will be required.

But this is not all that is required, as chemists, trained in this particular work, are not numerous in this country, and their necessity is shown when it is mentioned that in one German works, producing about 500 colors, we find 300 chemists employed; of these about 100 are engaged in analytical work, and the other 200 are in charge of the actual manufacture of the dyes, thus placing the production of only two or three colors under any one chemist.

After the capital has been supplied, and this new industry has been properly started, it will be necessary to secure proper legislation prohibiting "dumping" on our shores, a performance heretofore practised by the Germans, as well as a prohibition against an unfair restraint of our trade due to the arbitrary action of the German monopoly which is now allowed by foreign law, but not permitted by our own. Any scheme entered into must therefore necessarily depend upon an effective law which will prevent the control of our markets by foreign monopolies in the same manner as a domestic monopoly is now prohibited.

Advices received from Germany indicate that the German monopoly will re-enter the American market as soon as the war is over, and that it will make tremendous efforts to regain this lost business, being prepared to make extraordinary concessions in order to take the business from its infant competitors. It therefore is required of us that we place this new industry on a firm foundation as soon as possible, and that we seek such Federal legislation as will permit the continuance of the project without financial loss.

The dyestuffs subject could be treated at greater length, but the explosives, due to coal-gas residuals, also claim some little attention. The picric acid produced from carbolic acid, or phenol, is the base of "lyddite," used by Great Britain; of "melinite," used by France, and of "shimose" powder, used by Japan; but toluene, a tar or benzol product, is responsible for the production of the new explosive, "trinitrotoluene," commonly known as "T. N. T.," so much used in the present war.

Both picric acid and "T. N. T." are manufactured by a sulphonating and nitrating process, the method of operation in both cases being somewhat similar in detail. Phenol is produced by permitting that fraction of tar distillation coming over at a temperature between 150° and 230° C. (302° and 446° F.) to stand and cool until the naphthalene crystallizes out, after which the mother liquor is agitated in the presence of a solution of caustic soda, the latter combining with the phenol and forming sodium phenolate. This sodium phenolate, due to its weight, sinks to the bottom of the mixing chamber, whence it is drawn off and treated with sulphuric acid, this latter treatment setting free the phenol. This compound is now run into a still and fractionated, the phenol coming over at a temperature between 180° and 190° C. (356° and 374° F.) and crystallizing in sharp, needle-like crystals from the distillate. An equivalent weight of concentrated sulphuric acid is now mixed with the phenol, and the mixture is heated in an iron vessel by means of a steam coil to a temperature of slightly above 100° C. (212° F.). The mixture is next allowed to cool slowly, after which it is dissolved in twice its weight of water, and then slowly added to three times its weight of nitric acid, the nitration being completed by heating with steam after all fuming has ceased. This final mixture is now allowed to slowly cool down, thus permitting the picric acid to crystallize out, after which it is purified by washing with warm water, and then recrystallized.

This explosive, due to its acid nature, combines with metals, and thereby forms picrates, the latter in some instances being much more sensitive to percussion and friction than picric acid itself; this is a serious drawback, as it renders the shell containing this compound subject to explosion while in storage or during transportation, by heavy jolting. This, as well as many other disadvantages, caused the explosives manufacturers to turn their attention to another source, and they finally evolved the present-

day trinitrotoluene. This compound is made by first converting the toluene into a mononitro compound, after which it is treated with nitric acid at a slight increase in temperature, thus converting the mononitro compound into dinitrotoluene, after which the latter is nitrated in a sulphuric acid solution with concentrated nitric acid, the final product thus formed being trinitrotoluene. This compound is also produced from orthonitrotoluene by means of a sulphonating process similar to that used in the production of picric acid, after which it is nitrated and the resultant crystals are then purified in alcohol, being recrystallized and the alcohol removed in a centrifugal hydro-extractor.

In these statements I have tried to explain to you the wonderful properties possessed by a by-product which some years ago was considered a waste, and I trust my words will assist in calling your lasting attention to the possibilities of creating and maintaining an industry which can only redound to our credit and which will certainly add to our national wealth by not only conserving a vast amount of fuel, but which will also retain in our country a large sum of money which is annually expended in the purchase of materials which should be manufactured in the United States.

The True Nature of Speech with Application to a Voice-operated Phonographic Alphabet Writing Machine. J. B. FLOWERS. (*Proceedings of the American Institute of Electrical Engineers,* February 9, 1916.)—That speech is a rapid variation in intensity of the voice and mouth-tone according to definite sound patterns, called letters of the alphabet, is proved by showing that speech is the result of action of the mouth-parts in varying the intensity of the voice and mouth-tones and through photographs taken with the string-galvanometer of each letter sound of the alphabet, showing definitely the characteristic variation in intensity of each tone for each letter of the alphabet. From the curves the phonographic alphabet is obtained by measuring the variations in intensity of the main tone of the record.

A design for a voice-operated phonographic alphabet writing machine is described. The object of this device is to record speech automatically in ink on paper in the form of an easily-read, compact system of natural characters called the phonographic alphabet. Its design comprises a high-power telephone transmitter controlling electric resonator circuits, the intensity of currents in which is measured by the vibration of mirrors reflecting light upon a selenium cell connected to a special recording pen.

PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN,

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LIGHT PRODUCTION IN CEPHALOPODS.

This wonderful group of animals is counted as constituting the highest and best organized of the five classes of mollusks. As is well known, it is divided into the earlier group of Tetrabranchiata which lived in past ages and of which but one genus with four species is left in the living state, and the Dibranchiata or squids and octopi, which are of more recent origin, possibly from tetrabranchiate origin, and whose members are found in all the seas of our globe. Some 4200 species of extinct tetrabranchiate cephalopods have been described, while of the living dibranchiates we know of over 450 species.

We know but little concerning the tissue specializations of the tetrabranchiates, and in the living form of this order, the genus *Nautilus,* we find no luminous organs. It may well be possible—in fact, it is probable—that the extinct order did have numerous species that could produce light, although we are, so far, barred from any knowledge of this fact because of their fossil state, in which only the hard parts have been preserved. On the other hand, some of the most powerful light organs, under complete nervous control and supplied with the most perfect lens, reflectors, and other accessory parts, are found in the numerous species of the dibranchiates. We must except from this generalization, however, one branch of the Dibranchiata, the octopoda, whose members are almost entirely devoid of luminous organs. In a few cases such organs have been reported, but no sufficiently reliable report or descriptions are as yet forthcoming.

In spite of the large number of luminous squids and of the many descriptions of their various light organs we still lack exact and careful experimental work on any one form. Some very good observations have been made on the color of the light even of some deep-sea forms from as far down as a mile in depth, but

* Continued from page 400, March issue.

such work lacks good scientific research with the spectroscope and chemical experimentation. And in some of the reports of the great deep-sea expeditions of Germany, England, and France we find fairly good reports on the general appearance of the luminous organs of a number of squids, together with an account of their morphological distribution and good descriptions of their histological structure.

A number of generalizations can be made, at this point, as to the larger features of the light organs of these animals. The light organs are widely different in their method of operation, and we find two main types in this regard. First, we may consider those that have an internal combustion in which the secretion never leaves the cells that produce it. In the second place, we see other species of squids that possess a gland that ejects its secretion into the surrounding water, where the luciferine is brought into contact with the oxygen and the light is generated. This latter form is, perhaps, morphologically and physiologically, the more primitive.

Again, another general condition appears to be that almost all the light organs are found to be placed upon the ventral surfaces of the creature. And by ventral is meant the actual "under" side rather than the "morphologically ventral" surface. A partial or possible exception to this is found in the light organs that appear frequently on the arms in several forms. This condition has led to the inference that the animals might use their organs to illuminate the bottom of the sea over which they swim or some other object that is below them.

In the writer's opinion, however, the primitive purpose of these organs is the same as that of the chromatophores, to determine the color of the body. It is a well-known and accepted fact that most sea-living organisms of any size show a darker color on their upper surface and a lighter color, often a pure white, on their lower (ventral) surface. The darker colors are obtained by absorption of some light rays and the reflection of the remainder; the white by the reflection of all, or nearly all, the rays. In such a case the "white" result is obtained not by reflecting all the rays (which are few and weak in the sea depths), but by generating new rays in these photophores, which thereby become a sort of chromatophores.

In further confirmation of this idea, the writer calls attention

to the fact that the light from many squids has been reported to be of a decided bluish color. Thus any animal situated below such a squid and looking upward at it from below would see a bluish light that would blend with the sunlight, that reaches a depth up to as much as 100 fathoms in the daytime. And, as many of these creatures live in less than that depth or migrate at certain periods into less than 100 fathoms, as described for *Watasenia* by Sasaki, it seems that this condition of a mildly illuminated under surface would be of value to them.

While this theory would seem to apply best to those squids possessing a large number of lights distributed all over the ventral or lower surface, it could also be applied to those having a fewer number of larger lights: up to a certain point where their lights become very large and few and placed in unusual positions, and especially where they show as many as three distinct colors, some other unknown factors and uses must be explained, and no adequate explanation has been forthcoming. It is possible that in this case they are used as a mating adaptation.

The greatest number, by far, of the squid light organs appear to be, at first sight, of mesodermal origin; *i.e.*, the light-cells are deep under the outer layers of the skin. Even the lens tissues, and certainly the reflector cells, appear to have come from mesodermal tissues. No careful ontogenetic studies have made it possible to determine what the real facts are, owing to the difficulties of getting the proper embryonic and larval stages, but when we carefully study the few forms that possess an organ whose secretion is thrown out of the cell into the surrounding water, and make certain comparisons of these organs with the numerous organs whose secretion is consumed by the light processes inside of the cell body, we can see the strong probability that all of these organs have passed through a long phylogenetic development from earlier forms in which all the organs were derived from strictly ectodermal tissues. The writer feels sure that when we are able to secure and study the embryos of these rare animals we will find that all parts of the light organ, with the exception of the reflector layers, have an ontogenetic origin in the embryonic epithelium, and he bases this idea on the conditions found in the family Cranchidæ and in *Sepietta media* and *Heteroteuthis impar*. The reasons for this belief can perhaps be made plain most easily by a study of some of these forms.

The family of Cranchids are small, usually compact squids found in very deep water. They are pelagic in habit, swimming in these great depths of hundreds of fathoms, yet not living on or near the bottom. But few have been captured by the dredge or vertical tow-net, and yet some twelve or fifteen kinds have been described. The most interesting and valuable work on the subject is that by Dr. Carl Chun in volume eighteen of the scientific reports on the German deep-sea expedition on the steamer *Valdivia*.

Several light organs are found on some of the genera and species of this family. Their most frequent development is on the ventral surface of the eye. But, besides these, two large, symmetrically-placed light organs also appear on the visceral mass

FIG. 1.

Ventral view of the eye of *Liocranchia valdiviæ*, dissected out from the head. The four luminous organs are plainly seen, each with a slit-like opening into its interior. (After Chun.)

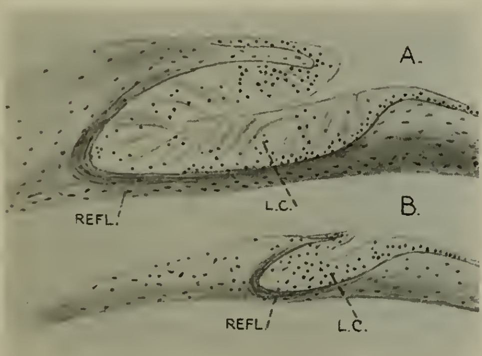
on several of the genera or species, particularly on the genus *Corynomina*.

Our interest centres on the eye organs of *Cranchia*, *Liocranchia*, and *Leachia*, because here we find a primitive condition which may, and probably does, represent an ontogenetic condition in most of the light organs of other squids. Fig. 1 shows a view of the under surface of the eye of *Liocranchia valdiviæ*, on which one may easily see four slightly protruding organs, each of which shows a slit-like entrance into its inner part. These are the ocular light organs. In the genus *Cranchia* there are thirteen such organs, while in other genera of the family they may be reduced to two in number or entirely absent. This under surface of the eye is covered by the projecting flap of tissue of the under surface

of the head, but this is a reflected flap, and thus these light organs are on a morphologically outer surface, and their slit-like opening communicates with the watery medium in which the animal lives.

When a section is taken through such an organ, perpendicular to the surface of the eye and at right angles to the line of the slit opening, we find a view as shown in Fig. 2, A and B. Here is seen a gland which is composed of what is practically simple epithelium, a continuation of the simple epithelium that covers the surface of the body in all mollusks, the squids included, but which is a comparatively thin and delicate layer in the squids. The transition of this

FIG. 2.



Vertical sections of two of the ocular light organs of the cranchid squid *Cranchia scabra*. B is a slightly more primitive form than A. *refl.*, reflector; *l. c.*, light-cells. (After Chun.)

body epithelium into the glandular epithelium (*l. c.*) of the light organ is shown in both A and B of this figure.

The gland consists of a single infolding of the surface lined by these glandular cells, which still maintain their perfect alignment and whose proximal ends rest on the connective tissue below, while the distal ends form a single line continuous with the outer body surface. Individually the cells are thick and glandular in structure and some of them show a denser condition of their cytoplasm than others, as A in Fig. 2 will show. Undoubtedly the luciferine is secreted in these cells. The light generated by these organs has never been studied, because the animals are rare and are usually dead or much exhausted when brought up from the great depths in the trawl or vertical net.

The question naturally arises: Is the light actually produced in the cytoplasm of the cells, or is the luciferine discharged from the cells into the lumen of the gland, there to meet the oxygen and enzyme and fulfil its function of light production? Several indications are present to show that the first method prevails in this case. First, the cells appear to be of a uniform texture rather than to have a proximal distal differentiation that would indicate the reception of food materials from the blood at the proximal surface and a discharge of the finished luciferine at the distal surface. This condition is further shown by the absence of any secretion whatever in the lumen of the gland as figured by Chun.

FIG. 3.

A few light-cells from Fig. 2A. More highly magnified. The nuclei and outlines of the light-cells are visible; also the capillaries, with their walls and elongate nuclei. (After Chun.)

Secondly, we find the somewhat unusual condition of blood capillaries entering the epithelium and passing between its cells to form a rich plexus at about the middle level. Were these cells to be secreting from the distal surface and securing their food material from the proximal it is unlikely that such capillaries would thus come up out of the mesoderm on which the epithelium lies. And their presence in a so far distal position in the epithelium would seem to indicate that they were as much there to carry off waste material, products of the combustion, as to furnish supplies for the secretory processes. Fig. 3 represents a portion of the epithelium from the fundus of one of these glands and shows the epithelial nature of the cells, as well as the presence of the blood capillaries and the tissues and nuclei of their walls.

All of these more primitive eye light organs show the presence of a reflector developed from certain connective tissues lying just below and in contact with the epithelial tissue (see Fig. 2, *refl.*). The cells of this structure are flat plates in form, and, since our sections cut them always at right angles to these surfaces, we find them to appear as strands containing nuclei in any such section. What the reflecting agent may be in these organs has never been worked out. In life it reflects daylight as a beautiful shimmering yellow. In the prepared sections the reflecting power appears lost. It seems not to be guanin as found in fishes and requires further study.

FIG. 4.

Section of an ocular organ of *Leachia eschscholtzii* to show a case in which the original invagination of epithelium has solidified and the lumen become almost obliterated. *ep.*, epithelial layer from which the organ was derived; *in.*, last trace of the closed lumen; *refl.*, reflector. (After Chun.)

As a next physiologically phylogenetic step in the development of the cephalopod light organ let us study one of the eye organs found in the allied cranchid squid *Leachia eschscholtzii*, and pictured in vertical section in Fig. 4, after Chun. Here it can be noticed at once that we have an organ directly comparable in many ways to the two we have just been studying. The photogenic cells of the structure are evidently an invagination and thickening of the outer body epithelium, as is testified by their plainly-seen continuity with this epithelium (*ep.*, Fig. 4). The point of invagination is represented by the depressed notch at *in.*, Fig. 4. An important change has crept into the structure of this organ, however. The photogenic cells in the fundus have abandoned their columnar and simple character and have divided and multiplied into a mass that fills the gland space and reduces the lumen to a theoretical space in the neighborhood of the former entrance to the gland. The lips of the opening remain and still

show their simple columnar epithelium as continuous with the ectoderm, although even part of this epithelium rests on the mass of light-cells instead of on the mesodermal connective tissue from which they have become separated by the intrusion of the swelling mass of light-cells below them.

The capillaries, which had already begun to grow out from their normal mesodermal field into the epithelium in the first organs described, here maintain this condition, except that, since the mass of epithelial cells in the gland was much larger and more compact, the capillary net-work is more like that found in an internal mesodermal structure. The walls of the capillaries show cells that are of a specific nature, thin walled and dense, and staining much darker than the surrounding photogenic cells. They evidently have been derived from the real mesodermal cells of the blood vascular system, and not by the transformation of the surrounding light-cells at the time that these circulatory channels are formed.

In this organ, too, as Fig. 4, *rcfl.*, will show, a well-developed reflector is present. It is evidently a modification of connective-tissue cells at this point, and should be studied further to see what the chemical and structural nature of the reflecting medium is and how the organ is developed. The structure of this organ confirms us in the idea previously expressed that in all these cranchid organs, no matter how epithelial in character and glandular in formation, the luciferine is not discharged into the water, but is oxidized *in situ*. Whether the exposed position of the secretory cells in the simpler forms of the organs is utilized for the absorption of oxygen or for the discharge of the products of combustion is not known.

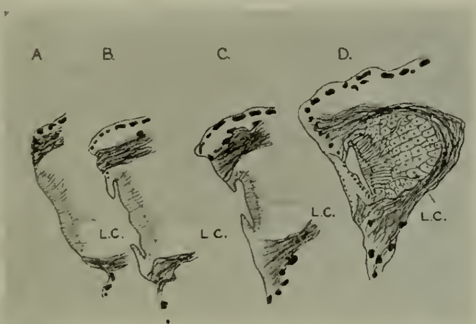
Before going further with the whole subject of squid light organs we must here consider a division that takes place in the phylogenetic series, so that, beginning with the open epithelial forms of organs just discussed, we find two types of organs. There are: first, a series of organs in which intracellular method of physiological lighting is continued and the phylogenetic cells are drawn deeper into the body, while various lens structures and corneal structures are developed over them, thus shutting them away from the external medium; and, second, a smaller series of organs in which the photogenic cells retain their simple epithelial arrangement on more or less deeply invaginated surfaces and

change the method of intracellular lighting to a method of external secretion and extracellular lighting that may be performed in morphological cavities or only upon extrusion from these cavities and contact with the water medium surrounding the living animal.

We will proceed with studies of the first-mentioned internal or invaginated forms, following the structures out in a series of typical squids to their highest specializations of light-cells and accessory structures, and then take up the second series of external secretion forms, which are far less common than the former kind.

Our next logical step in this study is to find some organ that will show us in its adult form how the photogenic cells have be-

FIG 5.



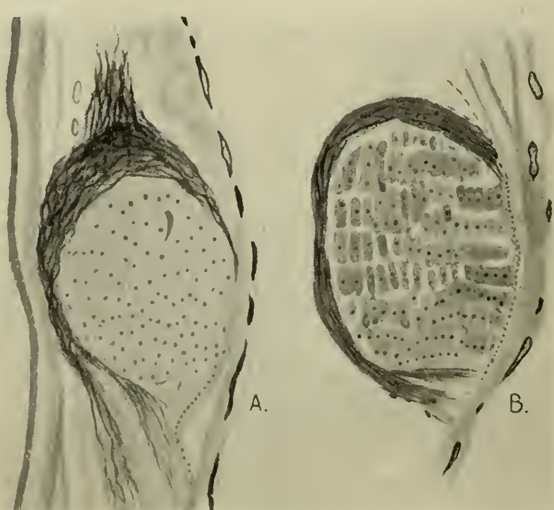
Sketches from four sections taken from an ocular organ of the cranchid squid *Leachia cyclura*. A in middle of organ. B, C, and D, sections taken at intervals toward posterior edge of organ where mesodermal elements begin to form flaps that will cover the epithelial light-cells, *l. c.* In D this covering is complete. (Modified after Joubin.)

come covered over by other tissues. Joubin has described such a formation from the cranchid squid *Leachia cyclura*. It is one of the organs found on the ventral surface of the eye, and is designated by him as being of "form D." Fig. 5 shows a series of five sections through this structure, the first one (A) being approximately at the middle of the organ, where the epithelial origin and position of the photogenic cells is quite apparent and their pseudostratification is indicated. In three other similarly oriented sections taken successively nearer to the posterior edges of the organ one can see the development of evaginated flaps of epithelium-covered mesoderm that nearly meet over the photogenic cells in C and are completed as an unspecialized layer in the last drawing,

D. This evaginated and consolidated area of mesoderm is now in a position to differentiate all or any of the structures that we shall see later in the squids, and that lie between the source of light and its point of exit from the body. These consist of lens, color screens and cornea, besides other less specific structures, such as blood-spaces, muscle tracts, etc.

The cranchids have thus, in their adult light organs, furnished us with the strongest indications, if not the actual proofs, of the

FIG 6.



Two other ocular organs from *Leachia cyclura*. These show the complete covering of the epithelial light-cells by mesodermal connective tissue to form a cornea. Chromatophores are present in this cornea. A is the result of a single invagination, one of whose epithelial lips is still visible. B is the result of several adjoining invaginations, as shown by the cords of cells. (After Joubin.)

ectodermal origin of all of the cephalopod light-cells. A further study of the embryonic and larval stages of some of the higher and much more complicated organs is desirable in order to complete our knowledge of this subject.

We are now at liberty to take up the study of the numerous more complicated forms of light organs in other families of squids with a better understanding of their meaning. This can be done with most interest and profit by describing the entire lighting systems of several of the numerous forms.

Fig. 6. A and B, shows two light organs, also from the eye region in *Leachia cycluria*, in which the occlusion of the photogenic cells is completed at every point. A shows such an organ that invaginated at one point only and in which the transitional epithelium is still plainly visible at the lower side of the invagination. B shows an organ that was undoubtedly derived from a multiple invagination which is as complete as the organ shown in A, so far as being covered by mesodermal tissues is concerned. The cords and rows of cells due to the several neighboring invaginations are plainly visible in the drawing.

FIG 7.

A school of squids, *Watasenia scintillans*, as they appear when alive and illuminating. (Drawn by E. Grace White after descriptions by Sasaki and others.)

The next study and discussion will be of the two Œgopsid squids, *Watasenia scintillans* and *Abraliopsis morisii*, the first being a common and abundant deep-water form found on the coast of Japan, and the latter in various parts of the South Atlantic and Indian Oceans, at great depths, where it is probably common enough but very hard to procure by our present fishing methods. Fig. 7 is a drawing of the appearance of *Watasenia* in life when shining.

Leaving out all other points of relationship, it is very apparent

that both these squids are possessed of practically the same luminous organs. These are of three kinds in both cases: a large number (several hundreds) of small, round light organs scattered over the ventral surface and sides of the mantle and outer surfaces of the more ventral arms; five much larger organs found in a row on the ventral surface of each eyeball; and, lastly, three very large and powerful organs placed in a close-set row on the internal tip of each of the two ventral arms. Of these three kinds of organs, those found on the ventral arms are by far the most

FIG. 8.

Transection of one of the brachial light organs of *Watasenia*. *c.*, nerve-cord; *l. o.*, light-organ surrounded by chromatophores. (Drawn by E. Grace White from sections.)

powerful and most highly specialized physiologically. In spite of this, however, they are the most simple structurally and represent a condition but little advanced upon the simple epithelial organs found in the cranchids. Fig. 8 shows one of these organs from *Watasenia* cut in a transverse section of the arm. The tissues of the arm appear as a nerve cord (*c*) with the surrounding muscle connective and epithelial tissues, and on the inner side is the large luminous organ (*l. o.*), which is much larger in diameter than the arm it is partly imbedded in.

In structure it consists of a large, globular mass of photogenic cells of great size (about 50 microns), packed rather closely together and almost surrounded by a layer of heavy chromatophores.

Each cell (Fig. 9) contains a single central nucleus of considerable size, with a typical chromatin pattern of large-sized particles surrounded by a narrow zone of a delicate and undifferentiated cytoplasm. The large bulk of peripheral cytoplasm is composed of much denser strands and loops closely interwoven and containing between these strands and loops a large number of spaces

FIG. 9.

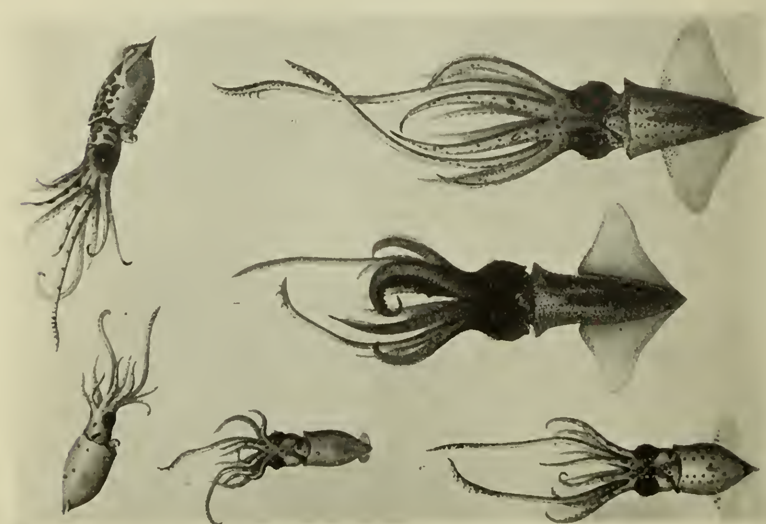
One of the light-cells from the brachial organ of *Watasenia*. Shows nucleus in centre, strand-like arrangement of cytoplasm, and capillary (*cap.*) entering and branching in cell-body. (Drawn by E. Grace White from section.)

which were vacant in the rather poorly preserved specimens in the writer's possession. No granules appeared to be present, and it is supposed that the luciferine which these cells must have undoubtedly contained was in a fluid form that was dissolved out by the method of fixation (weak formalin).

An interesting feature of the structure of this tissue was the rich net-work of capillaries that branched through it. The ter-

minal twigs of these capillaries even entered the individual cells and branched into a finer net-work inside of them (*cap.*), thus being in a position not only to effect food, respiratory, and excretory exchanges, but also to supply the oxygen necessary to the chemical method of light production. We know on the best of authority that this organ is really a luminous organ. Its light has been described by Watase, Berry, and Sasaki, and a paper on the subject is in course of preparation by Professor Ishikawa. The light is discharged in all directions as a flash or a series of

FIG. 10.



Figures showing the external appearance of the adult and young of the deep-sea squid *Abraliopsis morisii*. (After Chun.)

flashes, and it is a more powerful light than that of any of the Japanese fire-flies. In color it is bluish-white, with a tinge of purple or violet as described by Sasaki. Fig. 7 shows a school of these squids in motion through the water with their lights showing.

When seen in the daytime, in bright daylight or sunlight, the living organs show a greenish iridescence which points to the presence of some sort of a reflector. Such a reflector, however, does not appear in the rather poor sections at our command, but a very thin reflecting layer might be present on the proximal surfaces of the chromatophores that are found on three sides of the

organ and, to a limited degree, on the fourth. It is doubtless true that when the light process is going on the chromatophores are contracted into almost invisible points. Otherwise the light would be almost cut off.

In his wonderful work on some luminous squids captured by the steamer *Valdivia*, Dr. Carl Chun describes the organization of the squid *Abraliopsis morisii* (Fig. 10) and refers to its homologous gland-like organs of the same number and size and situated on the corresponding ventral arms. Not having been able to observe the creature alive, and not having seen the light, he referred to these structures as gland-like organs of unknown function. He mentioned the possibility that they might be luminous organs, but finally decided that they were not, because the mass of gland-like cells (the structure is almost precisely like that in *Watasenia*) were entirely shut off from the outside by heavy overlapping chromatophores.

This very natural mistake was due to the fact that he did not realize how contractile and expansible the chromatophores are. We know that a squid can become entirely red or brown by expanding the chromatophores, or entirely transparent in the next few seconds by contracting them into tiny, widely-separated masses that are invisible to the eye. In this way the *Watasenia scintallans* is observed to shine in bright, quick flashes. Whether this is done by a nervous control of the light process or by a sudden contraction and expansion of the heavy black chromatophores or by a combination of both is not known. Either method seems possible. Thus we can feel sure that in *Abraliopsis* the six brachial organs do light; in fact, arguing from the condition in *Watasenia*, they are the brightest organs in the body.

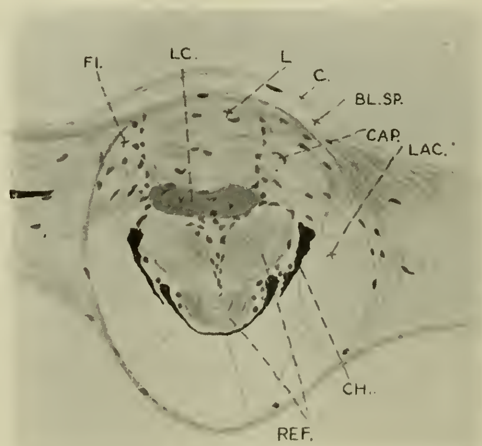
The next organs to be considered are the numerous, minute, bead-like organs found scattered all over the under surface of the mantle and extending out on to the outer surfaces of the ventral arms, and with some few even extending to the upper surface of the mantle. This type of organ is found, with some structural differences, in both the forms we are studying. We will examine the structures as shown in *Abraliopsis*, where it is somewhat better formed than in *Watasenia*.

The organs are about ¼ mm. in diameter and look like numerous black eyes with brown pupils set in among the chromatophores. When cut out and freed from surrounding tissue they

are almost round in shape, with an outer capsule holding its spherical form partly through the tension of the contained fluids. In a section taken through its centre and at right angles to the mantle surface we see a set of structures appearing like Fig. 11. This is a very highly specialized and well-differentiated organ, and yet one the major part of which can be correctly designated and its use explained, in part at least.

The outer surface of the organ is uppermost in the figure, a condition that is the opposite of what obtains in life, when, of

FIG. 11.



Vertical median section of one of the mantle light-organs of *Abraliopsis morisii*. *lac.*, lacunæ; *ch.*, chromatophores; *ref.*, reflectors; *l. c.*, light-cells; *l.*, lens; *fi.*, fibrillar support; *bl. sp.*, blood-space; *c.*, cornea. (After Chun.)

course, it faces downward. The outermost structure is a thin, tough membrane of connective tissue, bearing a very thin epithelium on its outer surface. This is the cornea, *c*. A space, *bl. sp.*, of some extent lies just inside of this and appears to contain blood or some other nutrient fluid, probably not directly connected with the general circulation, as under these circumstances the pressure would probably not be sufficient to maintain the tension necessary for the protection of the inner structures.

Inside of the blood-space comes the lens, *l.*, which is cylindrical in shape, with its outer surface in contact with the blood-space and its inner in contact with the principal mass of light-cells, *l. c.* This

lens shows both outer and inner surfaces to be convex. It is made up of flat plates of connective tissue, slightly curved and interwoven, and the nuclei are somewhat flattened in the direction of the plates. The index of refraction and focussing power of the lens have not been investigated—a research that would prove most interesting and profitable.

Surrounding the lens at its sides and forming a thick ring around it is a mass of tissue containing capillaries, connective-tissue fibres, and probably muscle-fibres. Its relation to the lens reminds one somewhat of the muscle-ring around the inner lens of the light organ of the crustacean *Nyctiphanes,* and if muscle-fibres are present their action would obviously change the focus of the lens.

Inside of the lens again is found the principal mass of photogenic cells, *l. c.,* forming a round plate of about one-fourth the thickness of the lens and composed of a mass of gland-cells whose limits are weakly defined. Their nuclei are large and round, and the cytoplasm has characteristic secretion granules, probably of luciferine. Fine capillaries are numerous between the cells, and their nuclei are elongate, thin, and dark staining. An injection of these vessels would be desirable to establish their courses and ramifications more plainly. The photogenic mass is slightly concave with reference to the outer direction.

Reaching proximal from this light-cell mass is seen a small, triangular mass of apparently less specialized cells, called by Chun the secondary light-cells. The writer feels that this is not a correct designation, and would feel more like concluding that they were cells that were in control of the remarkable set of reflectors found in contact with them. This idea is strengthened by the fact that on the other side of these reflectors is found a thin layer of similar cells whose function is more clearly of this character.

The reflectors themselves, *ref.,* are composed of two sets of hard fibrils or plates, the functional products of the cells above mentioned. One set appears in the form of some eight to ten nested cups, while the others form a series of nested, hollow, truncate cones whose smaller opening coincides with the innermost cup and whose outer opening embraces and is closed by the light-cell mass. Here again we do not know about the character of the reflecting material. Nor can we explain the very definite and peculiar forms of the reflectors themselves.

Proximal to the reflectors, and embracing them, is a cup-shaped mass of chromatophores that act as a final stop for all light that might pass as far backward as they are. These color-bearing cells probably are not contractile, as this would defeat their purpose. It is probably due to their presence that the whole organ as seen from outside gives the impression of having a black iris. The lens, backed by the reflectors, probably shows as the pearl-white pupil.

The last structure to explain is a large, cup-shaped mass of lacunia spaces, *lac.*, which in life undoubtedly contain a fluid. Whether this fluid acts in some nutritive way, or whether it only acts mechanically to maintain the rigidity of the organ's form, is not certain. Both functions could be performed, and possibly are.

Nerve-tissue has not been described in connection with the organ, but is most probably present, sending fibres to the central photogenic mass to control the secretion and combustion of the luciferine.

We will not describe the structure of the homologous organs in *Watasenia* because of the poor material on hand. It is probably built in much the same manner, and we refer the reader to papers about to appear on this subject.

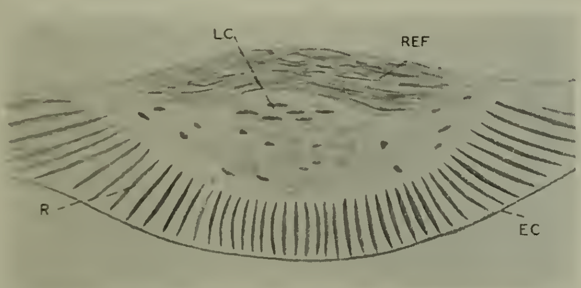
The third type of light organ found in the two squids we are discussing is that which appears as five large spots in a row on the under surface of each eye. They are very much the same in both forms, and we will examine those found in *Watasenia* (Fig. 12).

This organ is wide and flat, and it shows a much simpler structure than the last. Beginning with its outer surface, as we did in the previous case, we find that no lens or separate cornea is present, but the general ectoderm, reinforced by a fine layer of mesodermal connective tissue, forms the smooth boundary (*ec.*). Running inward from this boundary are a series of almost parallel, slightly converging rods (*r.*) of some heavy acid-staining (with eosin or fuchsin) substance. These rods show no visible attending cells, although we know that some nucleated cell is responsible for them. The rods are spindle-shaped, not round, but regularly flattened; they belly out smoothly toward the middle and taper down at both ends to weak staining fibrillar points; at the inner surface of the mass they merge into the mass of connective tissue that forms a flat, disk-shaped mass with thin edges. This mass is

weakly differentiated into three regions that merge somewhat into each other.

Its outer central part is evidently a weakly-formed lens substance slightly resembling the lens structures in the other light organs of the animal. It, too, is a cylinder, but very flat. The cells are much the same, but have not departed so far from the connective-tissue type. The inner central part of the mass is formed into thin, flat luciferine gland-cells (*l. c.*). They form a lens-shaped mass, and their outlines are quite distinct. As a point for the radiation of light they occupy an ideal position, and we can see at once that the rays of light so formed will enjoy a very equable distribution in passing out through the radiating rods spoken of before. This distribution seems to ignore the imper-

FIG. 12.



One of the ocular organs of *Watasenia scintillans*. *ec.*, outer surface of organ; *ref.*, reflector; *l. c.*, light-cells; *r.*, rods.

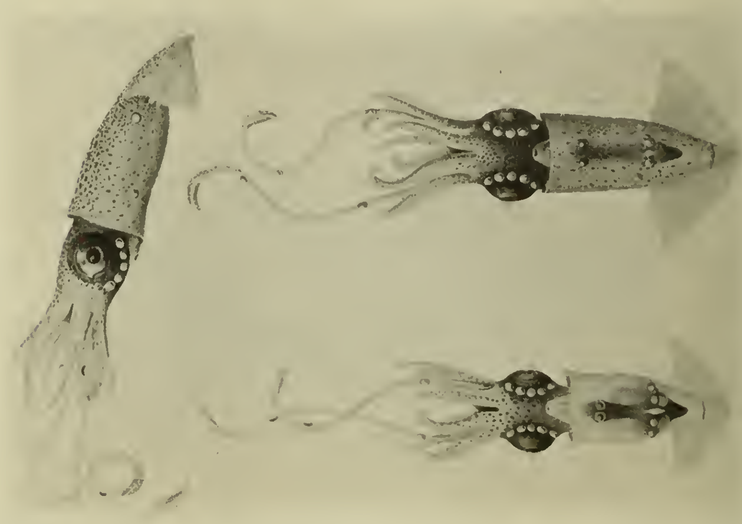
fectly formed lens, however. On either side of both lens and light-cell mass is the usual flat ring of connective tissue containing blood-vessels. It does not appear of much importance in this case.

The reflector (*ref.*) is of the type described in several cases before. Its plate-like masses of reflecting substance show as concave layers of strands in the sections. These strands are of a different substance from the outer rods, although they stain somewhat like them. No cell-bodies nor even nuclei were visible in the preparation. Such important structures are probably very small, as in many squid tissues.

Chun's descriptions of the ocular organs in *Abraliopsis* differ but little from this. All of the ocular organs are the same, or nearly the same, in both squids.

Among the squids with very highly specialized lights on its body is a rare form, of which only a few specimens have ever been captured, *Thaumatolampas diadema* (Fig. 13). The best studies that have been made are by Dr. Chun on the two beautiful specimens that were drawn up from about 3000 metres in depth in a part of the Indian Ocean. These were alive when secured, and, being at once placed in ice-cold sea-water, they lived for several hours and observations were made upon their light organs in the dark room.

FIG. 13.



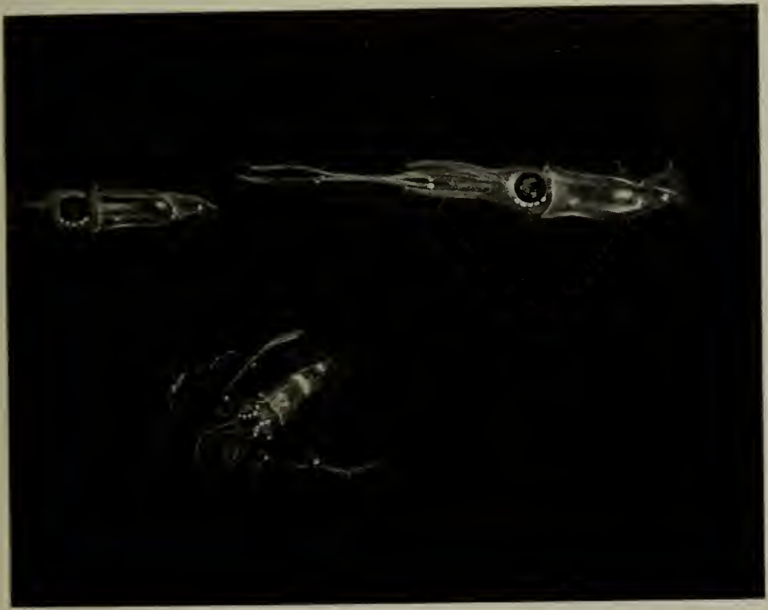
Drawings of the deep-sea squid *Thaumatolampas diadema*. The various (22) light organs appear as little knobs in the locations described in the text.

Each animal showed twenty-two large single organs on its body surface. These were distributed as follows: Two organs on the inner side of each tentacle arm, one about half-way between tip and middle of the arm, and the other about half-way between base and middle; five organs in a curved row (see Fig. 13) on the ventral surface of each of the eyes; two round organs of the same size placed one on each side of the ink-bag and just outside of the nephridial pores on the body surface; five lights placed in a row across the body-complex, the two outer ones being at the bases of the gills; and, lastly, one wide, angular light opposite the extreme

portion of the body-complex, just over the ovary or testis, and lying across the body axis on the inner mantle wall.

When living, these lights glittered so brightly that no difficulty was experienced in making a photographic plate of them; but the remarkable feature was that, while most of them shed a whitish radiance, the two anal lights shone with a clear ruby red, the middle visceral light lit up with a good ultramarine blue, while

FIG. 14



* Drawing of *Thaumatolampas diadema* as it would appear in the deep sea when alight. Two individuals swimming, one catching a fish. The last ones show the ventral surface with the lights. (Drawn by R. Bruce Horsfall.)

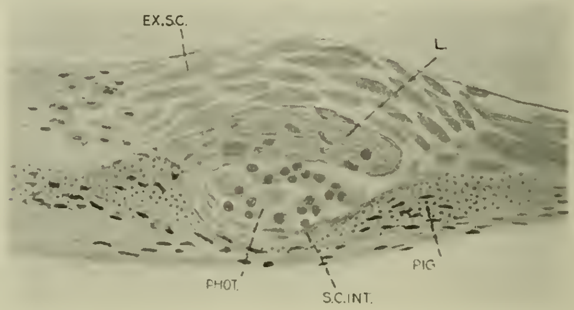
the two middle ocular lights displayed a clear sky blue. The question of how these colors were produced will come up when describing the organs in detail. (Fig. 14 gives some idea of the appearance of these animals when alive and shining.)

All these twenty-two organs are quite complex in structure and also of such variable complexity that a classification is hardly possible. Chun does classify them as to the principles on which they are constructed, but he had to arrange ten classes for the twenty-two lights! We will, then, simply describe the structure

of several of them, naming the known parts according to function, and describing those that cannot be easily identified. In some cases Chun said that he could not, with certainty, identify even the light-cells.

The distal tentacle organ shows a peculiar tendency, found in this and some other squids as well as in some fishes, to duplicate or multiply its light organs in the axis of light emission. The principal organ at this point is a large, rounded mass of light-cells arranged much as in *Watasenia* and with as simple or a simpler arrangement as to accessory structures, there not being any, not even the surrounding shield of dark chromatophores. The

FIG. 15.



Vertical section of the under member of one of the double-eye organs of *Thaumatolampas*. *ex. s. c.*, external "scale-cells"; *l.*, lens; *pig.*, pigmented cells; *phot.*, photogenic or light-cells; *s. c. int.*, internal "scale-cells." (After Chun.)

cells of this organ are considerably different in structure from those of *Watasenia*, being homogeneous with some few shallow indentations on the edge to allow of the passage of capillaries and nerves between them. Some of these indentations are deeper and may represent peripheral vacuoles in which luciferine combustion takes place. Numerous nerves and blood-vessels enter this very large mass of photogenic cells.

The nerve-cord of the arm lies on one side of this mass, and on the other lies a more peripheral light organ, more of the type of the other organs found on the body. It shows a small body of light-cells and a very large mass of corneal and reflecting cells surrounding this mass. We will not describe its structure further, merely calling attention to the fact that it has no connection with

the large central organs, but appears to have been added to them by later evolutionary processes along with the other highly specialized organs on the rest of the body.

Another interesting organ is the one found on each end (anterior and posterior) of the row of five organs on the ventral side of each eye. This, like the last, is a double organ, one placed at the surface and the other directly beneath it. Of the two, the inner, while smaller, is the most perfect, and we will examine it in the usual vertical median section (Fig. 15).

The specific cells of this organ are the group of photogenic cells found in the figure at *phot.* They are like those previously described with a good supply of capillaries and nerves. The mass rests in a shallow, cup-shaped layer of biconvex, lens-shaped cells which appear in section as spindle-shaped (*s. c.*). This cell is a heavy mass of cytoplasm with a small, flat nucleus on one side and its cytoplasm filled with a series of closely-applied flat plates of some firm, dark-staining substance. These plates are for the purpose of handling light in some way, but, owing to the fact that they appear both below and above the light-cells, the problem cannot be solved without further study. Light passes through the outer layer; that is certain. Possibly they possess lines that act as a diffraction grating in whichever direction the light strikes them. Beneath these "scale-cells" lie mesodermal cells that contain a brown pigment (*pig.*). This evidently acts to prevent the further contact of the light with the ordinary tissues of the eye.

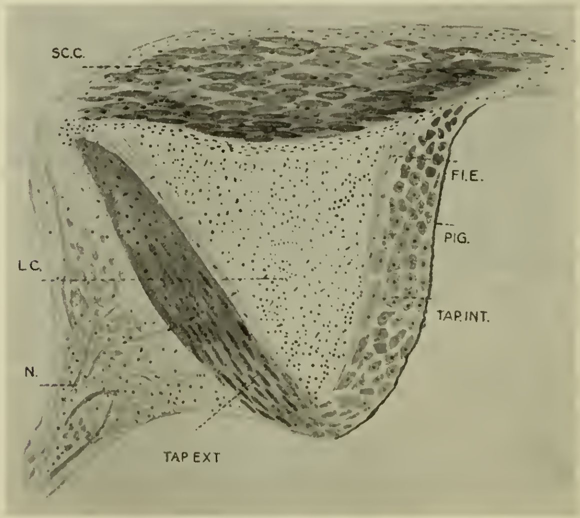
Outside of the light-cells is found a flat layer of fibrous cells of a definite color and somewhat like the cells of the lens in the mantle organ of *Abraliopsis*. This structure may represent a lens in spite of the small use that a lens would appear to have in this location (*l.*). The cell boundaries are not visible, and the fibrils of the tissue appear to reach from side to side of the structure, pursuing a curved or winding course, although they are not matted or wound up with each other.

Outside of this lens structure comes the thick layer of external "scale-cells," with their layers of plates (*ex. s.c.*), the same kind as those below the light-cells, but more than twice their size in diameter. This layer represents the outside of the organ and rests against the light-cells of the outer portion of the entire organ (not shown in the figure).

This outer and larger part of the organ will not be discussed

except to call attention to the fact that its outer layer of cells (" scale-cells," too) does not entirely cover the light-cells, which on the median edge of the organ reach to the surface, thus giving a clew to their ectodermal origin. The writer hopes that such an origin will some time be proved when the embryos and larvæ of this interesting squid can be secured by a diligent use of the vertical net. This should be possible when the nations take up science again instead of war and send out the deep-sea expeditions that have shown us so much of interest and value.

FIG 16.



Median section of one of the anal light organs of *Thaumatolampas*. *sc. c.*, scale-cells; *l. c.*, light-cells; *tap. int.*, internal tapetum; *tap. ext.*, external tapetum; *n.*, nerves going to light-cells through external tapetum; *pig.*, pigment layer on inside of internal tapetum; *fi. c.*, fibrous cells of lamellar layer. (After Chun.)

The two large, red anal light organs will next claim our attention. The most interesting point about them is that they are ruby red, both when not lighting and seen by daylight and also when shining in the dark by their own light. The structure shows some interesting points, but also many that are not yet explainable. In Fig. 13 may be seen the organ as it appears from the ventral side before the mantle has been cut away. Fig. 16 is a drawing of a median vertical section that gives a good idea of its general structure.

The light-cells appear here as a large, triangular mass, one of the largest masses of light-cells seen in any of the organs of this squid. In structure these photogenic cells are much the same in all of the organs of this squid. Only in external form and size do they differ, some being compact and large, while others have become more or less elongate, as may be seen in parts of the middle ocular organ.

The triangular mass of light-cells is lined on its two internal surfaces by a layer of connective-tissue cells whose cytoplasm has developed fine lamellæ that lie parallel with the surfaces of the mass (Fig. 16, *fi.c.*). These lamellæ are represented by lines in this view where they are cut in cross-section. The nuclei of the cells, whose boundaries are not discernible, are round, and they are distributed at regular intervals through the mass. The outer (laterad) and inner (mediad) lamellar cells form a thicker mass in the ventral part than in the dorsal part of the organ. Their meaning is uncertain. They do not seem to indicate a reflection function, and may be merely connective in their operation.

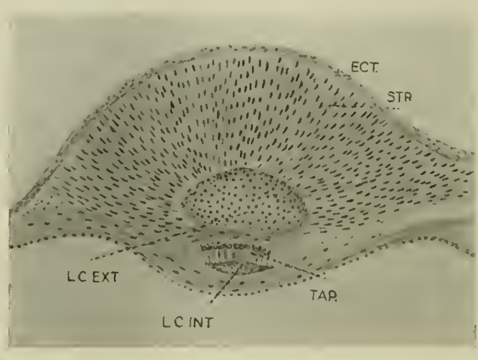
Outside of these again comes the tapetal layer, which is thick and composed of more massive cells with a coarsely granular content (Fig. 16, *tap. ext.* and *tap. int.*). A marked difference exists between the outer and inner portion of this layer on the two sides of the organ. The cells of the inner portion are larger and more compact, and in unstained sections show no pigment. Those of the outer layer are similar, flatter, and a brown pigment is mixed with their granules. The main nerve and blood supply comes from the lateral direction and runs mediad through this pigmented layer to enter the light-cell mass, then to branch and distribute itself among the light-cells. The tapetal cells appear to be the chief reflector cells of the organ. Those on the inner side of the organ are lined on their proximal surface by a thin layer of dark pigment which seems to fulfil the function of light absorption on this side, as the lighter pigment scattered in the outer tapetal cells must do on the outer lateral surface.

Ventrad from the light-cell mass and on its external surface (upper surface in Fig. 16) is a thick layer of the "scale-cells" of much the same structure as those described in the last organ. Since the light must pass through them, they may have much to do with its red color, although it would seem probable that the red pigment on the extreme outer surface of the organ (not shown in the sections) was the ray filter that did this.

When some scientist again has the valuable opportunity to handle a living and shining specimen this outer layer should be carefully scraped with a fine scalpel or needle to see if a white light is filtered through the red surface of the organ, or if the chemical processes taking place in the light-cells result in the red-colored light. That a white light should come from one organ of an organism and a red light from another is quite possible, as it actually occurs in an insect (*Phengodes*) to be described in a forthcoming chapter. This red-light organ offers great opportunities for careful experimental studies.

One more light organ must be studied in this wonderful animal because it involves an entirely different principle of structure.

FIG. 17.



Longitudinal vertical section of middle ventral light organ of *Thaumatolampas*. *l.c. int.*, light-cells of inner organ; *l.c. ext.*, light-cells of external light organ; *tap.*, epithelium-like tapetum; *str.*, rod layer resembling that in ocular organ of *Watasenia*; *ect.*, epithelium layer on outside of organ. (After Chun.)

That is the middle ventral organ, which shines with a clear blue light. This also is a double light, as some of the others are (Fig. 17). Its outer organ contains a rounded mass of light-cells resting proximally on the "scale-cells" of the inner organ. Its structure is simpler than that of the anal organ. Outside of the light mass is a wide, thick zone of cells that have formed long rods (Fig. 17, *str.*) of some firm substance, that run at right angles from the surface of the light-cell mass out to the epithelium that covers the whole distal surface of the organ. In this structure the organ reminds us of the ocular organ of *Abraliopsis*, and the function of the rods is probably the same—to distribute the light as a glow rather than to do the same by means of a lens.

The inner part of this ventral organ consists of another and far smaller mass of light-cells (*l. c. int.*) surrounded by small "scale-cells" on all sides except its ventral side, where, between the "scale-cells" and the surface of the light-cells, is a layer of long epithelial cells containing pigment and with their nucleus at the distal end of the cell (*tap.*). Or, to put it another way, the epithelium appears to have become inverted, probably by some of the invagination processes by which the organ was formed, and the nuclei are in the histologically proximal ends of the cells, although morphologically they are distal.

The above will give the reader some idea of the wonderful complexity and efficiency of the squid light organs and the necessity of further careful study in order that we may understand them better. This work must be done, as has already been stated, on a properly-fitted-out boat of size sufficient to enable the workers to remain at sea and study the specimens when captured.

Many other squids might be described, did space permit, with numerous organs built on many other principles of construction, but we must now leave all this class of cephalopods with light organs of the internal-combustion kind and go back to our beginning from the cranchid squids and take up the forms with the light organs of external combustion. There are comparatively few of these, nor will we be able to find any of a really simple character, such as those in which the organ is represented by a still open simple invagination. However, such a form will probably be discovered in the future when better facilities for work can be found.

ORGANS OF EXTERNAL COMBUSTION.

The two cephalopods that will serve us for examples of this type are *Heteroteuthis impar* and *Sepietta minor;* and these two will be described together because in the one case (*Heteroteuthis impar*) the writer has observed the living animal in action but was unable to secure material for histological study, while in the other (*Sepietta minor*) well-fixed material was obtained, although the activities of the squid were not actually observed. The structures of its organ, however, show that *Sepietta* must light very much, if not exactly, in the manner that *Heteroteuthis* does.

Heteroteuthis impar is a small and very beautiful squid found occasionally in the Bay of Naples and said to be more abundant off the more southern coasts of Italy. When brought into the

laboratory in good condition and allowed to rest quietly it may be taken into the dark-room and gently struck, as it swims in the aquarium, with a glass rod. Fig. 18 is a drawing to illustrate what may and usually does happen under these circumstances. The animal throws out of its siphon several little masses of mucus which show no light at the moment of ejection, but almost instantly, as the oxygen of the water begins to work on them, show a number of rod-shaped particles of a brilliantly luminous matter embedded throughout the very delicate mass. As the mass con-

FIG. 18.

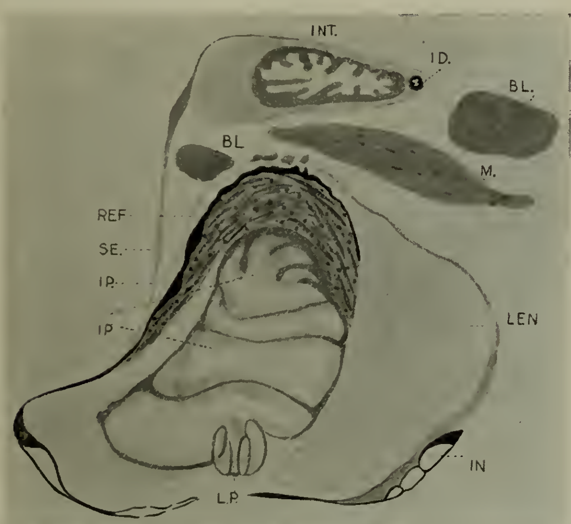
Drawing of a squid (as *Heteroteuthis impar* or *Sepietta minor*) when it lights by the external secretion method. (From a drawing by R. Bruce Horsfall, after descriptions by the writer, based on observations of *Heteroteuthis impar*.)

tinues to expand this light continues to glow brightly for as much as three to five minutes, after which it rather suddenly dies out. In color the light is the usual blue-green of luciferine when burning outside the body. The animal can repeat this process for a number of times, when it appears to have exhausted its supply of luciferine, and it is not possible, apparently, to keep it in captivity for a long enough period for the supply to be restored. A short and superficial morphological account of the structure of the gland which performs this function has been written by T. Meyer.

In place of this form we will turn for the structural details to the small squid, *Sepietta minor,* of which the writer secured good histological material at the Naples Zoological Station, in the deeper water of the Bay of Naples.

Upon opening the mantle of one of these little animals from the ventral side two bean-shaped, white masses are visible on the ventral surface of the pallial complex and placed symmetrically on each side of, and a little below, the anal opening. They lie against the sides of the ink-bag, and the reservoir of this ink-bag is extended to form a covering for the ventral side of the white mass.

FIG 19



Vertical section through the anal region of *Sepietta minor* to show the relation of the light organ. *int.*, intestine; *i. d.*, ink-duct; *m.*, muscle; *bl.*, blood; *i.p.* (upper figures), ink reservoir; *ref.*, reflector; *se.*, secretory epithelium of light-gland; *i. p.* (lower figures), luciferine reservoir of light-gland; *l. p.*, papilla through which luciferine is ejected; *len.*, lens.

A transverse section through this structure at about its anterior third shows a very interesting picture under the low-power objective (Fig. 19). The organ consists of two somewhat independent parts. The first of these is a very large lens (*len.,* Fig. 19), composed of a jelly-like connective tissue which appears fibrous when fixed and stained in section, but which in life is quite transparent. The brilliant white color of the organ in life is

due to a reflector layer (Fig. 19, *ref.*) on the dorsal or inner surface of this lens.

This reflector does not lie entirely against the lens, however, but only partly so, its middle portion being separated from the lens by the secretory organ of the gland. In Fig. 19 the reflector embraces this secretory portion more exactly and reverses its edge when it touches the lens. The reflector is made up of large, stout fibrils of a dense, dark-staining substance. These fibrils run in various directions, so that both longitudinal and transverse sections as well as oblique sections are visible in almost any section of the organ. In staining capacity they resemble the blood almost exactly when fixed in Bouin's fluid and stained with iron hæmatoxylin. They fade very slowly when the stain is extracted too much, while the blood masses fade suddenly when a certain point is reached.

The specific cells of the organ form a simple epithelium that has been invaginated from a single point into a number of large, flat, sac-like glands lying next to each other in a single row. The lumina of four of these sacs are represented in Fig. 19 by the cavities, two of which are marked, *i. p.* (lower figures). In those of a secondary amplification are present. Reconstruction from serial sections shows that all of these sacs open at a common point by separate openings through the papilla (Fig. 19, *l. p.*), which opens into the mantle cavity from the ventral surface of the organ to one side of the lens. This papilla is muscular and is tightly closed, but shows bodies of luciferine in its ducts. Material ejected from this papilla would be thrown into the excurrent siphon and thus out into the water, just as in *Heteroteuthis;* it is very difficult, however, to see this light, as the animals seem to have exhausted the power before arriving at the surface. Some small amount has been seen by the collectors of the Naples Zoological Station.

The presence of the lens would seem to indicate that some of the light was produced inside the sac-like glands. Such a lens would be of no use whatever if the luci-ferine burned only when it had reached the external sea-water outside of the animal's body. On the other hand, the presence of the papilla shows that something must be ejected. Possibly only the products of combustion are thus thrown out. The third possibility is that both methods are used, which, however, is rather unlikely. A few experiments

ought to solve this question, if one would perform them at Naples or elsewhere.

The secretory epithelium of these glands is shown in Fig. 20. It consists of large, cubical cells, most of which contain two nuclei placed obliquely in the cell. The cytoplasm is clear and no secretory granules are visible until near the distal surface of the cell, where they suddenly appear and form dense masses of the fine

FIG. 20.

Three cells from the secretory epithelium of the luciferine gland of *Sepietta minor*. *bl.*, blood-vessels. Nuclei are shown, one mitotic figure, and the distal mass of secretion.

brown granular secretion which partly fills the lumen of the gland. The cells form a single row and show many signs of exhaustion and degeneration from their work. Many of them collapse and are thrown off into the secretion. Others lose portions of their distal cytoplasm, which appears in lumps in the secretion. Of course, this means that there must be a constant regeneration of the epithelium, and we find a considerable number of mitotic figures in

the cells, one of which is shown in Fig. 20. It is evident that this division will result in two nuclei which will be placed at different levels in the cell, as are the two nuclei in the neighboring cells. Of the two nuclei, that which produced the outer one will probably degenerate after a short period of work and be thrown off with a portion of the cell, while the other will renew its activity by another division. Cell boundaries are very difficult to see in these large plastic cells.

The writer regrets that space forbids descriptions and discussions of the numerous other types of these beautiful luminous animals. It will well repay any naturalist to study them when the needful but expensive apparatus for their capture is available. Many hundreds of species swim in the deep seas, on the surface, and in the intermediate layers of the deeper oceans of the world.

To Make Soil Pressure Tests. (Office of Information, U. S. Department of Agriculture, February, 1916.)—Experiments on the distribution of pressures through soils are to be conducted at the Government's Arlington Farm, near Washington, by the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture. A specially-designed apparatus will be installed which will permit of earth-pressure measurements being taken in a large number of positions during a single application of the load. This feature is regarded as an important one, and it is hoped that an unnatural rearrangement of the soil from previous load applications in various positions will be thus avoided. Earth fills up to ten feet thick may be accommodated by this apparatus, and it will have lateral dimensions sufficiently large to permit of obtaining the full distribution of the load in all directions. Very comprehensive plans have been made for a practical solution of this problem, and it is hoped that definite results will be forthcoming within a short time.

The uncertainty of the distribution of pressures through soils, both vertically and horizontally, has long been recognized by the engineering profession, and several isolated experiments have been made with laboratory apparatus to gain knowledge on this subject. In magnitude the problem is such that its practical solution can be attempted only by the most thoroughly-equipped experiment stations. In application the final solution will be important to all branches of engineering, and it has seemed desirable that the department should devote a portion of its experimental resources to a most thorough and conclusive research of this nature.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE ILLUMINATION FROM A RADIATING DISK.†

By Paul D. Foote.

[ABSTRACT.]

THE consideration of the illumination from a radiating disk is of some practical value to engineers. Because of the fact that certain solutions of this problem which have appeared in technical journals have been in error, it was thought desirable to present the correct solution in a convenient and readily accessible form. The solution gives the illumination produced by a diffusely and uniformly radiating circular disk at any point in space on a surface parallel to the disk.

PHOTOMETRY OF THE GAS-FILLED LAMP.‡

By G. W. Middlekauff and J. F. Skogland.

[ABSTRACT.]

THE new high efficiency gas-filled lamp introduces variables not hitherto encountered in the photometry of incandescent electric lamps. On account of the comparative broadness of the filament spiral and the dyssymmetry of the filament mounting, there is considerable irregularity in the distribution of the light about the vertical axis. Consequently, when the lamp is rotated, as is commonly done in rating lamps at the factory, the light as seen in the photometer flickers so excessively as to render accurate measurements of candle-power practically impossible without the use of auxiliary apparatus. However, as is sometimes done, if two mirrors inclined to each other be placed back of the lamp, the flickering is so much reduced as to permit accurate candle-power measurements even at very low speeds of rotation.

* Communicated by the Director.

† Scientific Paper No. 263.

‡ Scientific Paper No. 264.

But this expedient does not eliminate the most serious trouble caused by rotation. It was found that at constant voltage both the current consumed and the candle-power are different when the lamp is rotating than when it is stationary, the current changing in one direction and the candle-power always in the opposite direction; that is, there is a change in the operating efficiency of the lamp. Furthermore, this change in efficiency may be either positive or negative, depending upon the speed, and it is about twice as great when the lamp is rotating tip up as when it is tip down.

Fortunately, from the standpoint of photometry, there is for each lamp in either position a particular speed at which the current and the candle-power have the same values, respectively, as when the lamp is stationary. Hence, with the lamp rotating at this speed its candle-power can be measured with accuracy in spite of its rotation. The speed for the above condition is practically the same for all lamps having the same number of loops in the filament; but for lamps having different forms of filament mounting it varies from lamp to lamp, being greatest for those having the smallest number of loops in the filament.

If the above precaution as to speed adjustment is not observed and lamps are rated while rotating at speeds ordinarily used in photometering vacuum lamps, the errors which enter may amount to as much as 1 to 2 per cent. in current, or watts, in one direction, and as much as 15 to 20 per cent. in candle-power in the opposite direction. Hence the voltage found for a desired operating efficiency may be so much in error as to give a lamp on test at this rated voltage a fictitious life value three or four times as large as the lamp would give if it were operated stationary at a voltage corresponding to that efficiency which, during the rating, was only apparent; that is, the lamp may be given credit for a much longer life than it really deserves. On the other hand, the speed may be such as to cause errors in the opposite direction, resulting in a lamp life much shorter than would be expected from the apparent efficiency rating.

Another peculiarity of the gas-filled lamp is that while it burns the blackening occurs, not all over the bulb in approximate proportion of the light distribution, as in the vacuum lamp, but principally at the top of the bulb, because the volatilized material is carried upward by the gas. Hence, in making a life test, a

true measure of the reduction in total light during the life of the lamp cannot be obtained in the usual manner by means of horizontal candle-power measurements, but by determinations of the total flux or mean spherical candle-power. This is accomplished most rapidly and conveniently by means of an integrating photometer, such as the Ulbricht sphere, in which the lamp is measured stationary, and thus all the complications arising from rotation are entirely avoided.

As to the cause of the variations observed in candle-power and efficiency when the lamp is rotated, it is concluded, from the results of a number of special tests, that the whole effect is produced by a change in the convection currents of the gas, a consequent variation in the temperature distribution in the bulb resulting in a change in the resistance, and therefore a variation in the current and candle-power of the lamp.

THE EFFECT OF IMPERFECT DIELECTRICS IN THE FIELD OF A RADIOTELEGRAPHIC ANTENNA.*

By J. M. Miller.

It has been shown by the measurements of C. Fischer and L. W. Austin that the curve which represents the variation of the resistance of an antenna with the wave-length of the oscillation has two characteristic features. Starting from the wave-length corresponding to the fundamental of the antenna, the resistance of the antenna rapidly decreases with increasing wave-length and reaches a minimum. As the wave-length is still further increased the resistance rises again, but in a linear manner. The initial decrease in resistance is explained by a decrease in the so-called "radiation resistance." It has been difficult, however, to account for the linear increase which takes place at the longer wave-lengths, and it is with the explanation of this feature that the paper is concerned.

Austin has offered an explanation of this phenomenon in that it is caused by dielectric absorption, and also concludes that it takes place in the ground. The present paper confirms Austin's hypothesis with respect to dielectric absorption, but finds that the energy loss is not caused by the ground, but by the presence of poor dielectrics in the field of the antenna. This conclusion

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* Scientific Paper No. 269.

is based upon the measurements of resistance of an experimental antenna constructed so as to eliminate poor dielectrics from its field and at the same time increase any effects which may be due to the ground. The linear rise in resistance at very long wave-lengths (even at telephone frequencies) was extremely small. It was then shown that the linear increase became considerable when poor dielectrics, such as wooden masts, trees, and buildings, were in the field, and that the resistance of the antenna was also increased at all wave-lengths. It was also shown that considerable energy loss may be occasioned by running the lead of an antenna inside of a building. The importance of designing an antenna so as to minimize the above sources of energy loss is pointed out.

LUMINOSITY OF A BLACK BODY AND TEMPERATURE.*

By Paul D. Foote and C. O. Fairchild.

[ABSTRACT.]

THE so-called "effective" or Crova wave-length of the luminosity of a black body may be considered a function of the temperature as follows: $\lambda_L = a + b/\theta + c/\theta^2 + \ldots$ The relation between luminosity, L, and effective wave-length is shown to be of the following form:

$$\frac{d \log L}{d\theta} = \frac{c_2}{\theta^2} \cdot \frac{1}{\lambda_L}$$

If $\lambda_L = a$, the temperature-luminosity relation takes the form suggested by Rasch. If $\lambda_L = a + b/\theta$, the relation is the Nutting equation. If $\lambda_L = a + b/\theta + c/\theta^2$, a new equation is obtained which is slightly more accurate than the Nutting equation. The three equations were checked by computations of the luminosity at various temperatures from the relation $L = \int_0^\infty VJd\lambda$ where $V =$ the visibility function and J represents the Wien spectral distribution law. The Nutting equation followed the computations satisfactorily; the new equation showed deviations no larger than errors involved in the computation of the luminosity, while the Rasch relation proved totally unsatisfactory

A luminosity pyrometer with a calibration based upon either the Nutting equation or the new equation should prove advantageous for the measurement of high temperatures.

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* Scientific Paper No. 270.

INCLUSIONS IN THE SILVER VOLTAMETER DEPOSITS.*

By G. W. Vinal and W. M. Bovard.

For the purpose of determining the absolute value of the electrochemical equivalent of silver and the absolute value of the faraday it is necessary to learn the amount of "inclusions" in the silver voltameter deposits. Several methods have been used in the past, but the results have been contradictory and uncertain. Lord Rayleigh [1] advocated heating the platinum cups with deposits to incipient redness as the simplest method of expelling the inclusions, which are chiefly water and silver nitrate. Richards and Anderegg [2] have recently used this method also, finding the inclusions to be large and variable in amount. We have repeated their experiments of heating the cups with deposits in a flame and have also made for comparison heatings in an electric furnace which was designed and constructed for this work by Prof. G. A. Hulett.

Preliminary tests on the empty platinum cups showed that they could be heated by either means and remain sufficiently constant in weight. When silver deposits are heated in the platinum cups alloying of the two metals takes place. This is slight if the time of heating is very short, or it may become pronounced as the time is increased. On removing the silver, the platinum cup shows stains which are brownish if the alloying has been slight, or black if heavily alloyed. Nearly all previous observers have noticed the alloying and one, Van Dijk,[3] has described the stains. But none of the previous observers seem to have been aware of the nature of these stains and the serious errors which they may introduce in the quantitative results. Our work has led us to conclude that these stains are platinum black and that they render the weight of the empty platinum crucible very uncertain unless the precaution is taken to heat the cups to incandescence, or to remove them by *aqua regia* before making further deposits. This heating process transforms the platinum

* Scientific Paper No. 271. (Complete paper to be published in the *Bulletin of the Bureau of Standards.*)

[1] *Phil. Trans. A.*, 175, p. 411, 1884.

[2] *J. Am. Chem. Soc.*, 37, p. 15, 1915.

[3] *Arch. Neer des Sci.*, ii, 10, p. 277.

black to platinum gray, and the loss in weight apparently suffered by the cups may be anything from 0.1 mg. to 5.0 mg., depending on the amount of material adsorbed by the platinum black. If the silver deposits had been made before this heating it is apparent that the losses in weight observed on subsequent heating could not properly be ascribed to the expulsion of the inclusions in the silver, as assumed by previous observers, since it would in part be due to the expulsion of dissolved material from the stains. The presence of either platinum black or platinum gray in the cup renders the cup unfit for use in measuring the electric current, since they exercise a catalytic action on the hydrogen ions present in the solution and therefore the amount of silver deposited is too small to represent all of the electricity which actually passed through the voltameter.

Taking these sources of error into consideration, we have made determinations of the losses in weight of deposits from pure electrolyte and find as follows:

	Per cent.
Mean 16 flame determinations	0.0041
Mean 9 furnace determinations	0.0038
Mean of all determinations	0.0040
Probable error of mean result	0.0003

With less pure electrolytes the losses are greater.

The Bureau of Standards published some time ago an absolute value [4] for the electrochemical equivalent of silver which was obtained by the silver voltameters containing especially pure electrolyte and an absolute current balance of the Rayleigh type. The value found was 1.11805 mg. per coulomb, which may be now corrected by subtracting 0.0040 per cent., and thus it appears that the value 1.11800 mg. per coulomb, which was adopted by the International Electrical Conference in 1908, is in reality within one part in one hundred thousand of the best value which we can now assign to this constant. On this basis we may compute the value of the faraday, using the present value for the atomic weight of silver (107.88), and find the faraday to be 96,494 coulombs. For general purposes the round number 96,500 is recommended.

A number of additional experiments were tried, such as re-

[4] *Bulletin Bureau of Standards* 10, p. 477.

peated heatings of the deposits, the effect of rough and smooth surfaces of the platinum cups, the effect of using voltameters of different sizes, a comparison of heating deposits scraped from the cathode with similar deposits not scraped off, and several experiments on the anode liquid. The results of these various experiments are given in full in the complete paper which will shortly be published.

THE CORRELATION OF THE MECHANICAL AND MAGNETIC PROPERTIES OF STEEL.*

By Chas. W. Burrows.

[abstract.]

This paper is a review of the work done in correlating the magnetic and mechanical properties of steel with special reference to the commercial application of the magnetic data as criteria of the mechanical fitness of a given steel and of magnetic changes under stress as indications of the state of strain.

A comparison is made between the magnetic properties and the other physical properties of steel. Among the mechanical properties that have been studied in connection with the magnetic characteristics are hardness, toughness, elasticity, tensile strength, and resistance to repeated stresses.

Another important phase of this subject is the variation in magnetic behavior as the test piece is subjected to the influence of stress. The correlation here is so close that the strains set up in a stressed bar are accompanied by simultaneous variations in the magnetic behavior, which change in character as the magnitude of the stress with respect to the elastic limit changes.

The magnetic test has been applied to the detection of flaws. Mechanical inhomogeneities of whatever origin are mirrored by corresponding magnetic inhomogeneities. A magnetic test may therefore be of assistance in detecting flaws in material where the vital characteristic is reliability. The results of the experimental work have been brought together in the form of numerous curves, which show in a concise manner the interrelation between the mechanical and magnetic properties of steel.

* Scientific Paper No. 272. (Complete paper will appear in the *Bulletin of the Bureau of Standards.*)

CONCLUSIONS.

The experimental evidence, of which only a small portion has been presented in this paper, seems to point to the conclusion that there is one, and only one, set of mechanical characteristics corresponding to a given set of magnetic characteristics, and, conversely, there is one, and only one, set of magnetic characteristics corresponding to a given set of mechanical characteristics.

Although there is no evidence to refute the preceding rather broad statement, the utility of this generalization is limited by the complexity of the relations due to the large number of variables and the lack of sufficient quantitative data. This lack of quantitative data, however, is only a temporary limitation and is gradually being overcome by the work of the author and of others who are working on this problem. The application of the magnetic tests is further limited by practical difficulties in testing irregular shapes. Even with these limitations magnetic testing in conjunction with mechanical testing may be expected to be of considerable value in determining mechanical properties.

Magnetic observations taken during the course of a tensile test will indicate the time when the true elastic limit, the yield point, the breaking-down point, and the ultimate strength are reached. In addition, the magnetic data will give some idea of the uniformity of the material.

If it is once determined what treatment is requisite for a given steel, a magnetic test may be used to determine whether or not the material has been brought into the desired condition.

It is quite possible that the magnetic data may be used to define a bar of steel. In no other manner than by a magnetic examination is it possible, without doing violence to the specimens, to determine whether two steel bars are identical in properties.

A determination of the magnetic uniformity of a piece of steel may be used as an index of the mechanical homogeneity.

A magnetic test indicates the character of the entire cross-section of the metal, rather than merely a surface phenomenon, as in the case of certain hardness tests.

Notwithstanding the possibilities of the magnetic test, it must be remembered that at present they are possibilities only. Before the magnetic characteristics can be of much practical importance, a great deal of investigation is necessary and a large number of accurate measurements on specimens of known chemical composition and heat treatment must be made.

Before a magnetic test can be of service as an indicator of the mechanical characteristics in any particular case preliminary work must be done to determine the most suitable magnetic data and also the minimum amount which will give the desired information. Among the magnetic characteristics which may be used are permeability, residual induction, coercive force, hysteresis energy, etc., and each of these may be taken in connection with any one of a great number of magnetizing forces.

GENERAL DESIGN OF CRITICALLY DAMPED GALVANOMETERS.*

By Frank Wenner.

[ABSTRACT.]

The user of a galvanometer is concerned with the conditions under which the damping is good or critical, the time required for the deflection to reach a steady value, or in ballistic work a maximum value, and the sensitivity to the quantity which the galvanometer is used to detect or measure; that is, he is concerned in the performance or operation constants which necessarily depend upon the inertia constant, the damping constant, the restoring constant, the dynamic constant, and the resistance. The latter are the intrinsic or construction constants which depend upon the size, proportions, kind of material, etc., used in the construction and are therefore of interest to the designer and maker of the galvanometers. The relations existing between these two sets of constants are of interest to both the user and maker of galvanometers. They are, however, of more interest to the maker, since they may be made to serve as a basis for predetermining values for the construction constants such as will give specified values for the operation constants.

The paper gives the relations existing between each of the operation constants and the construction constants. This is done for each of four classes of measurements in which galvanometers are used critically damped. In the first of these the sensitivity with which the user of the galvanometer is concerned is to current, in the second it is to voltage, in the third it is to current impulse,

* Scientific Paper No. 273.

and in the fourth it is to voltage impulse. These relations are then used in establishing a procedure for finding a set or sets of values for the construction constants such as will give previously selected or specified values for those of the operation constants which pertain to the class of work in which the galvanometer is to be used. This procedure constitutes what we shall call the general design and is the problem which receives the main consideration.

It is pointed out that in any of these classes of measurements the user is concerned with at most only three operation constants, while the galvanometer has five intrinsic constants. Consequently it must be possible to choose values for some of the intrinsic constants arbitrarily or within definite limits and find values for the others such as will give the specified values for the operation constants.

It is shown that in any case we may choose arbitrarily a value for the resistance. However, in those cases in which the power available in the galvanometer circuit is definitely limited the resistance and air damping should both be made as low as practicable if we wish a high sensitivity, since any power dissipated in the resistance or air friction reduces the amount available for twisting the suspensions or turning the magnet. Having decided upon a value for the resistance, it is shown that an upper limit for the air damping may at once be calculated. Choosing a smaller value and using the equations given, values for the remaining intrinsic constants may be calculated.

Where the constants of the galvanometer can have no appreciable effect upon the magnitude of the current we may choose arbitrarily a value for any other one of the intrinsic constants in addition to the resistance, and by means of equations given calculate values for the remaining intrinsic constants such as will give previously-selected values for those of the operation constants pertaining to the class of measurements in which the galvanometer is to be used.

The finding of a set of values for the construction constants such that the galvanometer will be critically damped, have the desired deflection period or ballistic period, and the desired sensitivity to current, to voltage, to current impulse, or to voltage impulse, under the conditions in which it is to be used, is a matter which cannot be explained fully in a brief abstract. The reader,

therefore, if interested, is referred to the complete paper, copies of which may be obtained after about April 15, on request addressed to the Director, Bureau of Standards, Washington, D. C.

INTERFERENCE MEASUREMENTS OF WAVE-LENGTHS IN THE IRON SPECTRUM (3233 A–6750 A).*

By Keivin Burns, W. F. Meggers, and Paul W. Merrill.

The wave-lengths of 403 iron lines were measured by means of interferometers. An effort was made to determine standards at intervals of about 10 Ångstroms. This was accomplished in the greater part of the spectrum from 3233 A to 6750 A, in which region the International secondary standards exist. As far as possible, lines of all intensities were measured. These measurements probably constitute as satisfactory a group of standards as can be obtained from this portion of the iron spectrum.

The arc spectrum of iron was used in accordance with the recommendations of the International Wave-length Committee. The method of procedure was that of Buisson and Fabry.[1] Most of the wave-lengths were determined from three or more interferometers, in which the orders of interference ranged from 15,000 to 60,000 waves. The International secondary standards were used in this comparison instead of the fundamental cadmium standard. The former are the means of three independent comparisons with the primary standard, and our use of them probably gives more accurate results than could be obtained by a direct comparison with the primary standard, which would involve the corrections for atmospheric dispersion and the difficult phase change determination. The mean difference between the present observations and the International standards is about one part in four million.

Comparisons with all the grating observations of iron lines which have been made on the I. A. system prove that more secondary standards were needed to obtain the highest accuracy in grating interpolations. Some of the grating observations show a difference in wave-length which is a function of the intensity of the line. The measurements with the interferometer appear to be quite free from this effect.

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* Scientific Paper No. 274.

[1] *Journal de Physique,* 7, p. 69, 1908.

Over 600 lines, including those measured, were examined by means of three or more interferometers in order to discover their limiting orders of interference. This gave an idea of the width or sharpness of each line. The data on sharpness were then correlated with intensity, pole effect, and pressure shift. Change in wave-length from the centre of the arc to the pole, or by pressure, is most likely to occur with lines which are broad even in the centre of the arc. The interferometer measurements were found to be comparatively free from pole effect. In general, the faint lines and those of moderate intensity are sharper than the strong ones, but the width of the average line, expressed as a proportion of the wave-length, appears to be constant throughout the spectrum.

THE RELATION BETWEEN COMPOSITION AND DENSITY OF AQUEOUS SOLUTIONS OF COPPER SULPHATE AND SULPHURIC ACID.*

By H. D. Holler and E. L. Peffer.

[ABSTRACT.]

SOLUTIONS of copper sulphate and sulphuric acid varying in concentration from 0 to 20 per cent. of each solute were made up and their densities determined at 25° and 40° C. The solutions were made of a known composition by weight in order to avoid the influence of temperature in their preparation. The density measurements were made by weighing in the sample under investigation a sinker of known mass and volume.

The effect upon the density by the addition of definite amounts of copper sulphate to sulphuric acid solutions and of definite amounts of sulphuric acid to copper sulphate solutions is shown graphically.

The close agreement in the density of solutions of the same total concentration is also shown by the same curves.

The density of copper sulphate-sulphuric acid solutions, within the range studied, is approximately a linear function of the concentration.

A method for determining and adjusting the composition of copper sulphate-sulphuric acid solutions for electrolytic copper baths may be devised from the results of this investigation.

* Scientific Paper No. 275.

NOTES ON THE BAUMÉ SCALES IN USE IN THE UNITED STATES.*

By H. W. Bearce.

[ABSTRACT.]

THE paper gives the origin, history, and present status of the Baumé scales in use in the United States, with special reference to the scale used in the petroleum oil industry. It is intended to correct certain misinformation in regard to the basis and time of adoption of the American Standard Baumé Scale for liquids lighter than water. It is of interest in connection with the Petroleum Oil Tables recently issued by the Bureau of Standards (Circular No. 57).

STANDARDIZATION OF AUTOMOBILE TIRE FABRIC TESTING.†

By W. S. Lewis and C. J. Cleary.

[ABSTRACT.]

THIS work was undertaken with the view to standardizing the more important methods of tests made upon 17¼-ounce cotton tire fabric. There was found little or no uniformity in the methods of testing employed by the various mills, and this had given rise to confusion in the interpretation of results of tests. In order to assist in the betterment of this condition, the Bureau, in coöperation with fabric and tire manufacturers, undertook to determine the methods of test most suitable for these fabrics.

The chief causes of variation in test results are due to different tensile strength testing machines, dimensions of test specimens, moisture content of specimen at time of test, method of sampling, and lack of uniformity in the material. Several long series of comparative tests were made to determine which of the several proposed methods for ascertaining each particular physical property of the fabric would give the most consistent and reliable results.

* Scientific Paper No. 276.

† Technological Paper No. 68.

TENSILE STRENGTH DETERMINATIONS UPON DIFFERENT TESTING MACHINES.

This investigation was undertaken to ascertain what differences in the results of tensile strength tests are obtained with testing machines commonly used by the trade. Tests were made at four mills employing different machines, and check tests were made at the Bureau of Standards. Tensile strength test specimens were so cut from the fabric and prepared that the variation in the material was reduced to a minimum. The differences thus found between results obtained from tests at the Bureau of Standards and the mills were large in most instances. An extreme case was that of one machine which gave results about 40 pounds too high upon fabric having a tensile strength of about 225 pounds.

DIMENSION OF TENSILE STRENGTH TEST SPECIMENS.

Five forms of test specimens were found in common use in the testing laboratories, but of these only three were studied, because they were more generally employed and seemed the most practicable. These three different dimensions of test specimens constituted one-inch-wide strips, two-inch-wide strips, and the so-called grab test. In the strip method pieces are cut slightly wider than one and two inches, depending upon the width desired, then ravelling down to one or two inches respectively.

The grab test differs in that the cloth is not cut and the test is made by placing the fabric (intact) between jaws of testing machine which are made one, two, three, or more inches wide.

The results of more than 2000 tests show that the one-inch strip method is fully as satisfactory, as regards accuracy and reliability, as the others. For several reasons, mentioned in the paper, the one-inch method is more desirable, and this dimension has been adopted for one year by many of the large manufacturers and consumers of this fabric.

MOISTURE CONTENT OF FABRIC AND ITS INFLUENCE UPON THE WEIGHT AND TENSILE STRENGTH.

The quantity of uncombined water present in the cotton fibre has a marked influence upon the weight and tensile strength. From preliminary tensile strength tests the results have shown

that for each 1 per cent. of moisture content, upon the basis of 100 parts dry material, there is an increase of tensile strength of approximately 7 per cent. This difference would mean an increase of 80 pounds in tensile strength of a 17¼-ounce tire fabric if the moisture content were increased from 3.5 per cent. to 8.5 per cent. or 5 per cent. Under this same 5 per cent. added moisture a 17¼-ounce tire fabric would increase 25 pounds in weight in a 500-yard roll. It is therefore necessary to adopt standard conditions in order to make comparable tests. Two methods were studied; *i.e.*, (1) drying the fabric samples in such a way as to eliminate the question of moisture entirely, or (2) exposing the test samples to a standard atmosphere until they have absorbed all the moisture they will absorb and the samples have come into equilibrium with the atmosphere.

It was found that greater uniformity between individual tests was obtained by drying the test specimens and eliminating all water except that of chemical composition.

METHOD OF SAMPLING FOR DETERMINING WARP TENSILE STRENGTH.

Tire fabric is usually made about 60 inches wide and shipped in rolls varying from 100 to 1000 yards in length.

A common mill method of procedure is to cut from the roll a piece of fabric 10 inches long and the full width (60 inches), then from the centre three test pieces from the warp direction are selected for tensile strength tests. These test pieces were never more than 3 inches wide, therefore only 6 to 9 inches out of the 60-inch width were tested, *i.e.*, leaving more than 50 inches untested.

The Bureau and others made exhaustive tests upon test pieces cut at various places across the full width. A compilation of these results shows little differences in tensile strength at any place within 2 inches of the selvages. By taking test pieces well distributed from selvage to selvage the weakest and strongest parts of the fabric would be found; therefore the Bureau recommends that the average of the results of such tests should be taken as more fairly representative of the strength of the fabric.

THE EFFECT OF CERTAIN PIGMENTS ON LINSEED OIL.*

By E. W. Boughton.

[ABSTRACT.]

The constants, including yield of ash, or raw linseed oil mixed with white lead in paste form, showed no material change in 25 months. Storage in partially-filled containers for one year of raw linseed oil mixed with white lead and with white zinc (in the proportions of paint ready for use) and exposure to air of films of such mixtures resulted in sufficient combination of oil and pigment to cause the extracted oils to yield amounts of ash that were much larger than those obtained from the oils used to prepare the mixtures. Exposure to air of films of these pigments mixed with boiled linseed oil also caused appreciable combination of oil and pigment. When white lead and white zinc were mixed with linseed oil fatty acids considerable combination of pigment and fatty acids occurred. The amount of fatty anhydride combined as zinc soap was nearly four times as great as that combined as lead soap, the calculations being based on the amounts of ash yielded by the ether extracts of the pigment—fatty acids mixtures and the ratios of the combining weights of zinc oxide and lead monoxide. The results as a whole indicate that white zinc combines with the free fatty acids of linseed oil more readily than does white lead. Of the three pigments, white lead, white zinc, and China clay, the former showed the greatest accelerative effect on the oxidation of raw linseed oil in films composed of pigment and oil, while China clay had the least accelerative effect. When a mixture of raw linseed oil and China clay was kept in a partially-filled container for one year the constants of the oil were materially changed, while raw linseed oil with chrome yellow and with zinc yellow under the same conditions showed practically no change. In drying films, however, the accelerative effects of the two yellow pigments on the oxidation of the oil were much greater than that of China clay.

THE TESTING OF GLASS VOLUMETRIC APPARATUS, 8th EDITION, REVISED.†

The circular contains specifications for glass volumetric apparatus, including burettes, pipettes, flasks, cylindrical graduates,

* Technologic Paper No. 71.

† Circular No. 9.

specific gravity flasks for Portland cement, Babcock test bottles, etc.

The principal change in the new edition is the adoption and recommendation of the abbreviation "ml" instead of "cc." for designating the millilitre, the metric unit of volume employed in all volumetric work.

Specifications have been added for several new graduates for weights and measures inspectors.

STANDARD DENSITY AND VOLUMETRIC TABLES, 5th EDITION, REVISED.*

THE circular contains tables for use in measurements of density and volume of such liquids as water, alcohol, sugar solutions, petroleum oils, etc., and special tables for use in the calibration of glass volumetric apparatus and hydrometers.

In the new edition the tables have been rearranged and several new tables added.

INVAR AND RELATED NICKEL STEELS.†

[ABSTRACT.]

CIRCULAR No. 58 of the Bureau of Standards describes in considerable detail the physical properties, microstructure, and constitution of the nickel steels, with particular reference to the alloy of zero expansion known as "Invar." The circular is a compilation of data from many sources, the pioneer work of Hopkinson, Osmond, Dumas, Guillaume, and Guillet being particularly emphasized, and rather full accounts being given also of the more recent investigations carried out by Hegg, Tammann, Chevenard, and many others.

A large portion of the text deals with the thermal expansion and constancy of invar and its characteristics as a length standard in bars, wires, and tapes. The text is accompanied by numerous tables and figures illustrating the various properties not only of invar but of the nickel steels in general. There are chapters on the magnetic, electrical, mechanical, and thermal properties, applications and sources of supply, and brief accounts of microstructure and constitution.

* Circular No. 19.

† Circular No. 58.

Experiments with Filaments Heated Electrically in Volatile Liquids. S. W. J. SMITH. (*Proceedings of The Physical Society of London,* vol. xxviii, part i, December 15, 1915.)—These experiments originated in the use as a resistance in a 200-volt circuit of an ordinary 100-volt incandescent lamp filled with paraffin oil. It was found most satisfactory, both as being able to absorb more power than with a vacuum and also to withstand momentary overload much better. When the current is flowing there is naturally a strong current of hot oil up the legs of the filament. When sufficient current is used, bubbles form on the filament, but these, instead of rising to the surface, run down the legs against both gravity and the upward current of hot oil and come off at the bottom.

Further investigation disclosed another more striking phenomenon. Placing the 100-volt lamp in a 100-volt circuit in series with a variable resistance (conveniently a water-trough), it was found possible, by momentarily cutting out most of the resistance, to obtain a single bubble along the wire. This bubble, instead of escaping at either terminal, travels backward and forward between the two, " looping the loops " of the filament in a fascinating way during every journey.

The peculiarities of this phenomenon, which can be obtained with either direct or alternating supply, have been analyzed by examining the size and motion of the bubble under various conditions and also by using filaments of different materials and liquids of different boiling-points. It is shown from the experiments that a rapid fall of temperature from the wire through the liquid, in the region through which the bubble moves, is an essential condition of the phenomenon, and, also from theoretical considerations, how this condition can be used to explain why the bubble moves in the manner described.

Vibration of a Turbo-generator by Resonance. J. VICENAIF. (*La Revue Electrique,* vol. xxiv, No. 283, October 1, 1915.)—Every structure has a natural period of vibration whose rate in general terms is dependent upon its elastic properties and its mass. Subjected to periodic impulses of the same rate, the structure will vibrate in unison with them, resulting in objectionable and, when the elastic conditions are favorable, dangerous oscillations. A case of this kind is reported in the Russian periodical, *Vestnik Ingenerov.* A turbo-generator attached to a structural steel floor supported by steel columns, when running at its normal speed of 3000 revolutions per minute, caused such serious oscillations of the structure that it was found impossible to operate the unit. A remedy was found in elastically supporting the bearings of the rotating members. So supported, the rotating parts have a period of natural vibration which is no longer coincident with the rotational impulses, and the action of the spring supports reduces the magnitude of the impulses received by the structure as a whole to such an extent that their effects are extinguished by the damping properties of the structure.

NOTES FROM NELA RESEARCH LABORATORY.*

REFRACTION AND ACCOMMODATION IN THE DOG'S EYE: A CORRECTION.

By H. M. Johnson.

In a note which recently appeared in this journal[1] the writer asserted, on the authority of Freytag, that the refractive indices of the lens and fluid media of the dog's eye are practically identical, and that several other species of infra-primate mammals suffer under the same condition. If this assertion were true, its significance would be very great indeed, since in such case the animals concerning which it is made could not change the focal distance of the eye by any mechanism of accommodation which mammals are known to possess.

At the time my note was published, I had been unable to procure a copy of Freytag's original article.[2] My assertion was based on my acceptance of a reference made by an American compiler to Freytag's work, in which a series of values were presented in tabular form as Freytag's. A comparison of the latter with the original article, which I have since obtained, shows that Freytag was incorrectly quoted by his reviewer, although the error is clearly unintentional. Freytag actually gives as mean values of the refractive indices in young and old dogs: for the aqueous humor, 1.3349; for the vitreous humor, 1.33483; and for the lens, values ranging between 1.4498 and 1.4666, depending on age. These differences are greater than those obtaining between the refractive indices of the lens and fluid media in the human eye, and are comparable with the differences found in the other mammals which Freytag studied.

In the individual dog which I studied no clear evidence of

* Communicated by the Director.

[1] "Visual Pattern-discrimination in the Vertebrates—V. A Demonstration of the Dog's Deficiency in Detail Vision," in "Notes from the Nela Research Laboratory," Journal of The Franklin Institute, December, 1915.

[2] Freytag, G.: "Die Brechungsindices der Linse und der flüssigen Augenmedien bei der Katze und beim Kaninchen," *Arch. f. vergl. Ophthalmologie*, vol. i, 1909–10.

accommodation could be obtained. Momentary fluctuations in refraction varying from 0.25 to 0.75 D occasionally appeared during a prolonged examination. These may have been caused by accommodation, but they are as readily explainable on other assumptions. The facts are quite consistent with the results obtained by Boden,[3] who refracted the eyes of 100 dogs both before and during mydriasis.

These individual dogs apparently make little or no use of their mechanism of accommodation. If this is generally true of dogs as a class, it would seem that the defect is retinal rather than in the accommodatory apparatus itself. If it may be assumed that the stimulus to accommodation is indistinctness of the retinal image, it is evident that an animal whose retina is relatively insensitive to detail would have relatively slight stimulus to accommodation.

As regards the conclusions which I drew from the experiments reported in the above note, I still feel quite safe in applying them to the dog. They cannot properly be extended to cover other infra-primate mammals, however, until more is known about the extent and range of accommodation in the latter.

A FORM OF THE HOLBORN-KURLBAUM OPTICAL PYROMETER ADAPTED TO A WIDE RANGE OF LABORATORY USES.

By W. E. Forsythe.

THERE has been constructed for use in Nela Research Laboratory an optical pyrometer that is thought to have some advantages over existing forms.

In this pyrometer are used tungsten pyrometer lamp filaments, and, as these are quite small (diameters 0.0015 to 0.0025 inch), an eye-piece with quite large magnifying power had to be employed. The mounting of the pyrometer lamp is so constructed that all possible adjustments, such as raising and lowering, moving the filament across the field of view, turning and tipping the bulb, can be easily obtained. The holder of the pyrometer lamp is so arranged that it can be rotated in a collar

[3] Boden, Rudolf: "Ueber den Refraktionszustand des Hundeauges," *Arch. f. vergl. Ophthalmologie*, vol. i, 1909–10.

in such a manner that the pyrometer filament can be set at any desired angle with respect to a lamp filament or other source that is being studied. The objective lens is fixed so that, with a very short rack for focussing, adjustments from a magnification of two times down to a focus for parallel light can be easily obtained.

Limiting diaphragms are placed between the objective lens and the pyrometer filament and also between the pyrometer filament and the eye-piece. An opening is left just in front of the lamp-holder for the purpose of inserting rotating sector disks, as it has been shown that when rotating sector disks are used they should be placed as near the pyrometer lamp as possible.

The support for the pyrometer permits of all possible adjustments, such as turning, tipping, raising, and lowering. In the completed description to be published in the *Astrophysical Journal* are given some reasons for using tungsten pyrometer filaments.

A FILTER FOR SPECTROPHOTOGRAPHY.

By M. Luckiesh.

In a great deal of spectrophotography it would be desirable to have available a photographic emulsion of uniform spectral sensibility and an illuminant having a uniform spectral distribution of energy. Such ideal emulsions and illuminants are not available, therefore it is customary to resort to colored filters to obtain the same final result. Templates might also be used. However, it is a long and tedious task to make an accurate filter for a given combination of photographic emulsion and illuminant. The writer has used a simple scheme for a number of years which involves what might be termed a "spectrophotographic filter." A photographic plate (of the kind to be used in the investigation) is placed in its ordinary position in a spectrograph, with the exception that the sensitive film is placed away from the prism or grating. Several spectrograms of the illuminant to be used are made on the plate, varying in exposure. In general these negatives should be of rather light density. After developing, fixing, and drying the plate, it is placed in the plate-holder in the original position and another plate is placed on top of it, the sensitive films being in contact. Spectro-

grams of the illuminant made through the negatives on the first plate will show quite uniform densities throughout practically the whole spectral range of chief sensibility. When the best exposure is found for the original plate a convenient "filter" can be made by exposing an entire plate by moving the plate-holder uniformly along the guides. After developing, fixing, and drying this negative, a wave-length scale may be ruled upon it, unless it has been previously photographed upon the plate. Obviously a "filter" must be made with the same kind of plate as that to be used with it. Successful results have been obtained with both grating and prism spectrographs. The scheme corrects for the dispersion of the prism for the latter instruments.

In the table results are presented which represent the transmission of the final spectrogram in different parts of the spectrum. Column F represents the transmission (related very simply to photographic effect) of the filter. This also gives an idea of the extreme non-uniform sensibility of available panchromatic plates. Column S represents the final effect, showing that this simple method very largely compensates for the non-uniform sensibility of the plates and the non-uniform spectral distribution of energy in the illuminant. The former, however, is more serious in general. Uses of this simple scheme are obvious.

Wave-length	Wratten and Wainwright panchromatic plate		Cramer spectrum plate	
μ	F	S	F	S
0.375	0.982	0.597	1.00	0.79
0.396	0.64	0.314	0.900	0.282
0.416	0.353	0.234	0.545	0.172
0.436	0.221	0.231	0.356	0.196
0.457	0.158	0.222	0.261	0.206
0.478	0.180	0.190	0.358	0.200
0.498	0.314	0.187	0.802	0.238
0.519	0.414	0.172	0.757	0.179
0.540	0.328	0.172	0.52	0.144
0.561	0.345	0.177	0.320	0.157
0.582	0.291	0.168	0.402	0.172
0.602	0.405	0.142	0.435	0.202
0.623	0.303	0.193	0.451	0.172
0.643	0.254	0.200	0.395	0.174
0.664	0.64	0.161	0.652	0.213
0.675	——	0.342	——	——
0.684	——	——	0.930	0.574

THE LAWS OF VISUAL MINUTHESIS: * THE THRESHOLD PREEXPOSURE TIME AND THE EQUILIBRIUM TIME FOR A PROJECTED NEGATIVE AFTER-IMAGE.[1]

By Leonard T. Troland.

THE following is a preliminary report of one of a series of investigations being carried out to determine the laws which govern the decay of a semicircular after-image, variously produced, but always projected on a circular, luminous field of its own diameter, so as to fill one-half of this field.

In the present experiment four different ranges of the spectrum were employed, and the brightness of the uniform stimulus fields in which they were presented were made equal, by the flicker photometer, to 31.6 candles per square metre. The stimulus field was provided with a central fixation point, always visible, had an angular diameter of 3.38 degrees, and was viewed through an artificial pupil—of 2.36 mm. diameter—against a dark background. Five minutes' dark adaptation was allowed before beginning a set of measurements. The results given are for the writer's right eye.

The relation selected for study was $t_q = f(t_p)$, where t_p is the preliminary time of exposure of the eye to the first semicircle, and t_q is the time from the moment of exposure of the second semicircle until the minuthetic (or "fatigue") contrast disappears. The three cases tested were: $t_p = 300$ seconds (which is practically equivalent to $t_p = \infty$), $t_p = 30$ seconds, and $t_q = 0$.

The last case involves a determination of the "threshold preëxposure time," or the minimum time which will produce a noticeable minuthesis under the given conditions. This was attempted by the method of "constant stimuli." Four hundred observations were made on each color, the right- and left-hand sides of the field being presented first, an equal number of times. If, at the first instant of exposure of the second half of the field, the preëxposed half looked darker than the other, the contrast

* The writer has proposed the term *minuthesis* to designate, in place of the inappropriate word "fatigue," any decrease in the sensitivity of a sense organ, due to stimulation.

[1] To be published in the *Journal of Experimental Psychology*.

was called negative; if brighter, it was called positive. The results follow:

Color	Wave-length, in $\mu\mu$	t_p in σ*	Number of trials: Right first, Positive	Right first, Equal	Right first, Negative	Left first, Positive	Left first, Equal	Left first, Negative
Red	666.5 – 689.3	35.0	1	27	22	2	30	18
		57.2	1	15	34	0	18	32
		78.6	0	6	44	3	7	40
		100.2	0	2	48	0	1	49
Yellow	574.2 – 587.4	35.0	9	19	22	2	13	35
		57.2	7	15	28	0	14	36
		78.6	4	12	34	1	8	41
		100.2	0	6	44	1	3	46
Green	516.0 – 525.4	35.0	12	23	15	7	28	15
		57.2	10	23	17	3	21	26
		78.6	12	13	25	4	10	36
		100.2	6	11	33	0	8	42
Blue	445.7 – 451.0	35.0	17	20	13	1	23	26
		57.2	14	16	20	0	11	39
		78.6	11	15	24	1	10	39
		100.2	0	5	45	1	1	48

* σ = 0.001 second.

Calculation of these results, by the traditional method of "right and wrong cases," judgments of negative contrast being regarded as "right," gives the following values for the threshold:

Color	Threshold time: Right first σ	Threshold time: Left first σ	Space error σ	Corrected threshold σ
Red	52.50 ($h = .0944$)	50.35 ($h = .03204$)	– 1.08	51.43
Yellow	46.50 ($h = .01231$)	– 4.198 ($h = .008115$)	– 25.35	21.15
Green	70.15 ($h = .01052$)	55.75 ($h = .01684$)	– 7.20	62.95
Blue	70.75 ($h = .01413$)	30.60 ($h = .01406$)	– 20.08	50.68

The large space errors are probably due to a slight lack of uniformity in the stimulus field.

The average values found for t_q, with $t_p = 30$, and $t_p = 300$ seconds, respectively, are given in the following table. Each average represents ten trials.

Preëxposure time, t_p, = 30 seconds

Color	Equality time, t_q Right first, seconds	Left first, seconds	Space error, seconds	Corrected value, seconds
Red	86.2 (A. D. = 2.2)	92.5 (A. D. = 3.0)	3.2	89.4
Yellow	90.6 (A. D. = 2.1)	95.3 (A. D. = 1.6)	2.4	93.0
Green	91.5 (A. D. = 3.1)	93.3 (A. D. = 3.8)	0.9	92.4
Blue	76.5 (A. D. = 1.8)	89.1 (A. D. = 3.8)	6.3	82.8
	Preëxposure time, t_p, = 300 seconds			
Red	156.8 (A. D. = 4.7)	143.9 (A. D. = 2.3)	−6.5	150.4
Yellow	180.0 (A. D. = 6.5)	164.1 (A. D. = 4.5)	−8.0	172.1
Green	162.4 (A. D. = 4.0)	152.4 (A. D. = 3.7)	−5.0	167.4
Blue	147.2 (A. D. = 3.8)	146.3 (A. D. = 4.3)	−0.5	146.8

Since t_q, for $t_p = 300$, represents closely equilibrium conditions of sensitivity, it may be called the "equilibrium time."

This work is now being repeated with other subjects and under improved conditions. The results are ultimately intended to test a theoretical equation for $t_q = f(t_p)$, deduced from assumptions with regard to the chemical nature of the retinal process.

Research on the Corrosion Resistance of Copper Steel. D. M. BUCK and J. O. HANDY. (*The Journal of Industrial and Engineering Chemistry*, vol. 8, No. 3, March, 1916.)—Sheet steel and iron-containing copper show greatly-increased corrosion resistance when exposed to atmospheric conditions. The most effective amount of copper to be used for this purpose is approximately 0.25 per cent. Smaller amounts of copper down to as little as 0.04 per cent. have a considerable influence in lessening corrosion, but the results are not so good as with the higher amount. Previous investigation has indicated that 0.15 per cent. copper is in nearly all cases as efficient as 0.25 per cent. Higher amounts of copper up to 2 per cent. give little or no added benefit. Copper is as necessary in the so-called "pure irons" to insure corrosion resistance as it is in normal open-hearth and Bessemer steels.

Pasteurized Milk. ANON. (*Scientific American Supplement*, vol. lxxxi, No. 2097, March 11, 1916.)—That there is no valid objection to pasteurization when properly performed, and that the process makes safer even the most carefully handled and inspected milk, is the conclusion of a new professional paper of the United States Department of Agriculture, in which are set forth the most recent conclusions of scientists in regard to this matter. According to this paper, it seems probable that within the next two years a large proportion of the milk supply in the large cities will be pasteurized. Before the value of pasteurization as a hygienic measure was as well recognized as it is to-day, it was practised in secret by a number of milk dealers as a means of preserving milk and preventing it from souring. Its commercial value in this respect is undoubtedly great, but its chief function is the destruction of disease-producing organisms. Proper pasteurization should destroy about 99 per cent. of all the bacteria in milk, although when the bacterial count in raw milk is low the reduction may be somewhat smaller. The efficiency of the process, it is pointed out, cannot be based on the percentage, but rather on the character of the bacteria destroyed.

The kinds of bacteria that remain alive after pasteurization depend on the temperature to which the milk is heated and the species of bacteria that are in the raw milk. Three processes of pasteurization, known respectively as the flash process, the holder process, and pasteurization in the bottle, are practised in this country. In the flash process the milk is raised quickly to a temperature of 160° F. or more, held there for 30 seconds to a minute, and then cooled quickly. In the holder process the milk is heated to a temperature of 140° to 150° F. and held there for half an hour. When pasteurization in bottles is practised, the raw milk is put into bottles with water-tight seal caps, which are immersed in hot water and held for 20 to 30 minutes at a temperature of 145° F. In this way the milk is not subjected to any danger of reinfection. On the other hand, the seal caps must be absolutely tight, and this involves increased cost. In general it may be said that the holder process is coming into greater favor than either of the others. This process permits of the use of lower temperatures, which for various reasons is highly desirable. Another method of pasteurization, or rather a modification of the present holder process, suggested by the Department investigators, is that of bottling hot pasteurized milk. The process consists of pasteurizing the milk by the holder process at 145° F. for 30 minutes, then bottling it while hot in hot bottles steamed for two minutes immediately before filling. After filling, the bottles are capped, and may be cooled by any of the systems in which the caps are protected. The bottles are sprayed with water or cooled by forced-air circulation. The bulletin concludes that pasteurization by the holder process is to-day the most effective means of obtaining safe milk.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting held Wednesday, March 15, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 15.

A report on the condition of the work of the Committee on Science and the Arts was presented.

The President announced that the presentation of certain medals recently recommended for award by the Committee on Science and the Arts was in order and recognized Mr. Charles E. Bonine, chairman of the committee, who introduced Mr. Clement F. Street, of New York City, to whom had been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for the Street Locomotive Stoker.

The Street is an overfed type of stoker. The coal is brought by a worm conveyor from the tender to a hopper and is elevated from the hopper by an endless chain of buckets to a point near the top of the back head of the boiler. The coal is then directed from this point to three firing points in the back head, and at these points steam jets blow it into the firebox.

Over six hundred Street Stokers are in successful operation.

The President presented the medal and accompanying certificate to Mr. Street, who returned his thanks for the honor conferred upon him.

Mr. Bonine was again recognized and introduced Mr. Frederick A. Hart, of New York City, to whom had been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

The elements of this machine are a standard Underwood Typewriter and a motor-driven adding and subtracting machine. The adding machine is so constructed as to be controlled by the typewriter, which is superimposed upon it so that the numbers written upon the typewriter may be transferred to the adding machine.

The President presented the medal and accompanying certificate to Mr. Hart, who expressed his thanks for the recognition of the inventions of himself and his co-workers.

Mr. Bonine was again recognized by the President and introduced Mr. C. D. Rice, a representative of John Underwood and Company, of New York City, to receive the Edward Longstreth Medal of Merit, which was awarded his company for developing their Combined Typewriting and Calculating Machine to a successful commercial form.

The President presented the medal to Mr. Rice, who thanked the Institute for the award made to the company.

Mr. Bonine was again recognized and introduced Mr. Benjamin G. Waggner, of Philadelphia, Pa., to whom the Institute had awarded its Edward Longstreth Medal of Merit for improvements in Prepayment Attachments for Gas Meters. This attachment is a device designed to provide simple and accurate means for the delivery of a predetermined volume of gas through a meter after the purchase price has been deposited in the cash-box and to insure the positive closing of the prepayment valve at the proper time.

The President presented the medal to Mr. Waggner, who thanked the Institute for the honor it had conferred upon him.

Mr. Hans Hanson, of Hartford, Conn., was also awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine, but was unable to attend the meeting. He expressed his appreciation by letter for the City's and Institute's action.

Arthur L. Day, Ph.D., Sc.D., Director, Geophysical Laboratory of the Carnegie Institution of Washington, then addressed the meeting on "Volcanic Eruptions." The speaker gave a *résumé* of the recent investigations made to determine the character of the chemical reactions which take place in volcanic activity and which are undoubtedly one of the important causes of such disturbances. The results obtained are based on studies made of the European volcanoes: Vesuvius, Etna, Stromboli, and Vulcano, as well as Lassen Peak in northern California and Kilauea in the Hawaiian Islands. Numerous colored lantern views were shown.

After a brief discussion the unanimous thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

[CORRESPONDENCE.]

To the President and Committee on Science and the Arts of The Franklin Institute of the State of Pennsylvania:

GENTLEMEN: Mr. R. B. Owens, Secretary of your Institute, has informed me that the City of Philadelphia, on recommendation of your Committee on Science and the Arts, has awarded me the John Scott Legacy Medal and Premium, and inquired if it would be convenient for me to be present at your next meeting on the evening of Wednesday, March 15, to receive the same in person.

In acknowledging receipt of the letter from Mr. Owens, I stated that, on account of serious deafness, I considered it wiser to remain at home, because I would be unable to hear any remarks usually made on such occasions.

Recognizing fully the significance and honor of being granted this award, I admit I felt some pangs of regret in denying myself the accorded privilege

of being personally present to receive it, but you readily understand that, under the conditions stated, the pleasure of being present might easily be more than counterbalanced by embarrassment, and for that reason I take this method of expressing my most heartfelt appreciation of the honor bestowed on me by the granting of this award, and if the work I have done, which forms the basis of this recognition, is even in a very small degree of real assistance in human activities and progress, I shall always feel that I have done something that should be a source of satisfaction to me.

As awards have also been granted to others in connection with my invention, I merely wish to express my personal feelings in regard to the assistance given me in the development of my original ideas. Without financial aid I could not have gone very far, and a great deal of credit is due to Mr. John T. Underwood, who undertook to furnish the necessary capital, an undertaking much more costly than I think he bargained for, and much more so than I had any idea would be the case; and, as my dealings from the first were with him personally, I am well qualified to speak of him in connection with this work. I wish to say that during more than thirteen years that have passed since I first met him there has never been the slightest misunderstanding between us that I am aware of, and that his word has always been as good as his bond, and I consider it a most remarkable feature that he always seemed to remember what either one of us had said, even though years had passed by, when one considers that he is a very busy man and engaged in many varied activities requiring his serious attention.

Considering that he has borne, personally, until very recently, the very great expense, and that so many years were required to develop this machine, he has shown a great deal of pluck and persistence, and I hope he will be rewarded some time for the faith he has displayed. Many another man, or set of men, might have become discouraged long before the desired results were attained.

While I am considered the originator of the more essential features of this invention, I did not have the technical knowledge required to put my ideas in the best mechanical form for manufacturing purposes, and it was our good fortune to secure the services of Mr. Frederick A. Hart, who took hold of that end of the proposition, and who is also the possessor of a great deal of inventive skill, which has been used with good effect to improve upon my ideas, which left much to be desired, particularly in regard to convenience and appearance. It has taken a vast amount of work to produce the machine as it now stands, and this work has been under Mr. Hart's supervision, and he is entitled to much credit for having worked hard and faithfully to produce a machine that would be satisfactory to the purchaser and user thereof. He did not work merely for the compensation he received, but to produce desired results, and there is a vast difference between these two objectives, and I am glad to know that he has been granted the same award as myself, as his work deserves fully as much recognition as mine, and, of the two, he has had much more to look after than I.

Mr. Rice has had something to do with the manufacturing of the invention, on account of his position as superintendent of the Underwood Typewriter Factory, but what I particularly want to refer to here is the fact that he was

the first, outside of those who made the original model, to see the interior mechanism and pass an opinion thereon, on which opinion Mr. Underwood based his decision to take hold of the invention. I passed a few anxious days waiting for the outcome of his report to Mr. Underwood, which I soon learned was favorable, and I felt a great burden lifted from my mind. I sincerely hope that final results have been satisfactory enough to Mr. Rice to prove that his judgment of the possibilities of the invention was not misplaced, and what might have happened if his opinion had been unfavorable no one knows, but I feel sure that it would, in all probability, have been impossible for me to have found as good financial support and otherwise congenial associates in this venture as it was my good fortune to find almost without effort.

The invention, as now produced, is the product of many minds, and I am glad to acknowledge that as a fact, and willing to give credit to every one who has helped to make it what it is to-day.

It was my good fortune to come along with my efforts at just about the right time. I knew nothing of what others had done in this particular line of endeavor, but nothing could have been successfully done very long before I started on this work in 1896. The typewriter was fairly well established at that time, and the adding machine was being forced to the front, against the opinion of many who considered it impossible for a machine to do what had been considered the work of the human mind or brain, but the machine won out, and business men were getting their minds prepared for the combined typewriter and computing machine, which will soon be a necessity in every business establishment of even comparatively small size.

The path of the inventor is more often full of thorns than of roses, and many a good invention and inventor falls by the wayside for lack of appreciation and the necessary means to develop it and present it to the world and to defend his rights in regard to patents, which latter is a costly process—so costly and full of pitfalls that a poor inventor stands a very small chance of obtaining his rights if he has an adversary with plenty of resources to hire the best legal talent obtainable.

Had I known the difficulties ahead of me in getting my patents, I would never have started, but it was a case of " when it is bliss to be ignorant, it is folly to be wise." I have been a party to eight or nine interference proceedings, and lost only one, which was of minor importance.

In conclusion, I wish to pay a word of tribute to the men who, by their generosity, have made possible the awards of medals, premiums, and diplomas to those who are considered to merit the same, and, in my own case, more particularly to John Scott, and also wish to express my sincere thanks to The Franklin Institute and its Committee on Science and the Arts for recommending my invention for the award of this medal and premium, and to assure them that I fully appreciate the honor of receiving this award.

Very respectfully,

(Signed) H. HANSON.

HARTFORD, CONNECTICUT, March 13, 1916.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March 1, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 1, 1916.

MR. J. A. P. CRISFIELD, *Chairman pro tem.*

The following reports were presented for final action:

No. 2654.—Circle Drawing Attachment for Microscopes. Certificate of Merit to Philip Atlee Sheaff, of Philadelphia, Pa., adopted.

No. 2655.—Prepayment Attachment for Gas Meters. Edward Longstreth Medal of Merit to Benjamin G. Waggner, of Philadelphia, Pa., adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 24, 1916, at 8 P.M. Mr. Louis E. Levy occupied the chair. The minutes of the previous meeting were read and approved.

Mr. William D. Uhler, Chief Engineer, State Highway Department, Harrisburg, Pa., delivered an illustrated lecture, entitled "Highway Problems of the State of Pennsylvania."

Mr. Uhler discussed the difficulties in taking care of the elaborate system of highways of the commonwealth. He pointed out the mistakes which were made when the roads were originally laid out, and showed how a more comprehensive system of main-travelled thoroughfares could have been established with benefit to the state. The general and specific maintenance of the roads was discussed; the methods of caring for the various types of roads found throughout the state were described, and it was pointed out that revenues sufficient to maintain these roads in proper condition must be provided before permanent construction can be undertaken.

After an interesting discussion a vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 2, 1916, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

George A. Rankin, A.B., of the Geophysical Laboratory of the Carnegie Institution of Washington, Washington, D. C., presented a communication on

"Portland Cement." The history of Portland cement was traced. The procedure used in the manufacture of American Portland cement was outlined, as were the reactions which occur in the kiln and the nature of the product obtained. The compounds which are formed on ignition of mixtures of calcium, aluminum, and silicon oxides were described, and the technic of fusion and of analysis of the product was outlined. The proportions in which these compounds occur in pure and commercial cements, and their relation to the "setting" of the cement, were discussed. The procedure to be followed in a further systematic study of the best composition of cements for various purposes was pointed out. The lecture was illustrated with lantern slides.

The paper was discussed by Messrs. Lesley, Humphrey and others. A vote of thanks was tendered Mr. Rankin, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 9, 1916, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

George C. Whipple, S.B., Gordon McKay Professor of Sanitary Engineering, Harvard University, Cambridge, Mass., member of the firm of Hazen, Whipple & Fuller, consulting engineers, New York City, delivered a lecture, entitled "The Element of Chance in Sanitation," dealing with the applications of the laws of probability to certain problems of vital statistics, epidemiology, water pollution, and water purification. With the help of lantern slides and specially ruled cross-section paper, Professor Whipple demonstrated the element of chance in making bacteriological tests of water supply, milk, etc., and also explained how this cross-section paper was useful in approximating the maximum rainfall that might be expected in any section where records had been kept of the rainfall and run-off for a number of years, and how such results could be used in determining the size of spillways for dams.

After a brief discussion, a vote of thanks was extended to Professor Whipple.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 8, 1916.*)

RESIDENT.

MR. HENRY BUTLER ALLEN, metallurgical engineer, Henry Disston & Sons, Tacony, Philadelphia, Pa.

MR. CHARLES W. ASBURY, vice-president, Enterprise Manufacturing Company of Pennsylvania, Third and Dauphin Streets, Philadelphia, Pa.

MR. CHARLES MILLER BIDDLE, JR., first vice-president, Supplee-Biddle Hardware Company, 517 Commerce Street, Philadelphia, Pa.
MR. CHARLES L. CONN, president, Giant Portland Cement Company, Pennsylvania Building, Philadelphia, Pa.
MR. WILLIAM H. DONNER, Morris Building, Philadelphia, Pa.
MR. FRANK B. FOSTER, manufacturer, The Congoleum Company, Morris Building, Philadelphia, Pa.
MR. R. H. NORTH, North Bros. Manufacturing Company, Lehigh Avenue and American Street, Philadelphia, Pa.

NON-RESIDENT.

MR. A. F. HUSTON, president, Lukens Iron and Steel Company, Coatesville, Pa.
MR. CHARLES L. HUSTON, vice-president and manager, Lukens Iron and Steel Company, Coatesville, Pa.
MR. FRANK P. MILLER, Frank P. Miller Paper Company, East Downingtown, Pa.
MR. GUYON MILLER, president, Downingtown Manufacturing Company, Downingtown, Pa.
MR. GEORGE W. RAMSEY, patent attorney, 700 Tenth Street, Washington, D. C.
MR. WILLIAM H. RIDGWAY, manufacturer and civil engineer, The Craig Ridgway & Son Company, Coatesville, Pa.
MR. L. D. VORCE, chemical engineer, vice-president, Tennessee Copper Company, 2 Rector Street, New York City, N. Y.
MR. WILLIAM H. WALDRON, manufacturer of machinery, New Brunswick, N. J.

CHANGES OF ADDRESS.

MR. RUSSELL L. BRINTON, 1751 North Sixty-first Street, Philadelphia, Pa.
MR. HENRY I. BROWN, care of Miss R. L. Keller, 137 South Fifth Street, Philadelphia, Pa.
MR. LUCIUS P. BROWN, 137 Davis Avenue, West New Brighton, New York City, N. Y.
MR. W. L. GARRELS, Webster Groves, R. R. 5, Box 107, Missouri.
MR. ALEXANDER P. GEST, Cynwyd, Pa.
MR. CLARENCE A. HALL, Cresheim Arms, Mt. Airy, Philadelphia, Pa.
MR. THOMAS SKELTON HARRISON, 1520 Locust Street, Philadelphia, Pa.
MR. FRED. T. HASCHKA, 135 West Seventy-eighth Street, New York City, N. Y.
MR. K. G. MACKENZIE, care of The Texas Company, 17 Battery Place, New York City, N. Y.
PROF. J. A. MOYER, State House, Boston, Mass.
MR. ROBERT S. PERRY, 31 Union Square, West, New York City, N. Y.
DR. SAMUEL P. SADTLER, 210 South Thirteenth Street, Philadelphia, Pa.
MR. H. R. STANFORD, Navy Yard, Philadelphia, Pa.
MR. JAMES H. WAHL, Hollis Court Boulevard, Bellaire, Long Island, N. Y.

NECROLOGY.

Lincoln Godfrey was born in Philadelphia, May 17, 1850, and died February 8, 1916.

He was educated in private schools in his native city and began his business career in the dry-goods house of his father. In 1873 he became a member of the firm of William Simpson Sons & Company, manufacturers of cotton goods. He was director of a number of financial institutions, insurance companies, and important industrial establishments. He became a resident member of The Franklin Institute on February 14, 1912.

Edward Rowland was born in Philadelphia on September 9, 1844, and died in his native city on February 29, 1916.

His membership in The Franklin Institute dates from May, 1878.

Dr. Louis Duncan.
John McIlhenny.

LIBRARY NOTES.

PURCHASES.

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KINGSBURY, J. E.—The Telephone and Telephone Exchanges. 1915.
MANN, H. LESLIE.—Text-book on Practical Mathematics. 1915.
OELSNER, G. H.—Handbook of Weaves. 1915.
POHL, R., and PRINGSHEIM, P.—Die lichtelektrischen Erscheinungen. 1914.
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WALKER, MILES.—Specification and Design of Dynamo-electric Machinery. 1915.
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BOOK NOTICES.

ORGANIC CHEMISTRY; or, the Chemistry of the Carbon Compounds, by Victor von Richter. Edited by R. Anschütz and G. Schroeter. Vol. 1, Chemistry of the Aliphatic Series. Newly translated and revised from the German edition (after Edgar F. Smith's third American edition), by Percy E. Spielmann, Ph.D., B.Sc., F.I.C., A.R.C.Sc. Philadelphia, P. Blakiston's Son & Co., 1916. 677 pages, contents and index, 8vo. Price, $5.

It is somewhat of an astonishment for an American reviewer to note the phrase "Preface to the First English Edition" when von Richter's book in English form has been for so many years a prominent feature of chemical teaching. On closer examination, however, we find that if "English" is not used in its Pickwickian sense, it is at least employed in the narrow sense of originating in, and being specially adapted for, England. The confusion between the two meanings of this noun gives much trouble,

and it might have been better if the present edition had been termed the "British" edition, especially as the older translation is almost always termed the "American" edition.

It is not necessary to dwell at length on the merits of Richter's book, nor on the merits of the translation. The work is a wonderful presentation of the facts of chemistry, and the rendition into English does great credit to the translator.

The book was printed in England. Paper, type, and press-work are excellent—no small matter in a work so rich in detail and containing so many complicated formulas. Especial praise must be given to the index, which is extensive and clearly printed, features in which possibly the translation much surpasses the German original, for Continental writers have always been weak along that line. The present volume covers half the field of organic chemistry, and will be followed by the chemistry of the cyclic compounds.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Elevators: A Practical Treatise on the Development and Design of Hand, Belt, Steam, Hydraulic, and Electric Elevators, by John H. Jallings, mechanical engineer and elevator expert. 224 pages, illustrations, 8vo. Chicago, American Technical Society, 1915.

North Carolina Geological and Economic Survey: Bulletin No. 24, Loblolly or North Carolina Pine, by W. W. Ashe, Forest Inspector, U. S. Forest Service. Prepared in coöperation with the Forest Service, United States Department of Agriculture. 176 pages, plates, 8vo. Raleigh, State Printers, 1915.

U. S. Bureau of Mines: Bulletin 86, Some Engineering Problems of the Panama Canal in Their Relation to Geology and Topography. Published with the approval of the Governor of the Panama Canal, by Donald F. MacDonald. 88 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1915.

National Association of Wool Manufacturers, Annual Wool Review, 1915. Domestic wool clip, imports of wool and woollens, and other statistical tables. 81 pages, plates, 8vo. Boston, Rockwell & Churchill Press, 1916.

The Colorado Industrial Plan, by John D. Rockefeller, Jr., including a copy of the plan of representation and agreement adopted at the coal and iron mines of the Colorado Fuel and Iron Company, 1916. 95 pages, diagram, 16mo. No place, no date.

U. S. Bureau of Standards: Technologic Paper No. 60, Microstructural Changes Accompanying the Annealing of Cast Bronze ($Cu88$, $Sn10$, $Zn2$), by Henry S. Rawdon, Associate Physicist. 17 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1916.

Address by Dr. Nicholas Murray Butler, President of Columbia University, in the city of New York, to the members of the Union League of Philadelphia, at Founders' Day Celebration, held Saturday evening, November 27, 1915. 14 pages, 12mo. No place, no date.

War Taxes and Waste, speech of Hon. James A. Frear, of Wisconsin, in the House of Representatives, Monday, January 10, 1916. 42 pages, quarto. Reprinted from the *Congressional Record,* January 13, 1916.

CURRENT TOPICS.

Small Incandescent Lamps and Special Illumination Problems. R. P. Burrows. (*Transactions of the Illuminating Engineering Society,* vol. x, No. 9, December 30, 1915.)—The small incandescent lamps commonly classed as "miniature lamps" are coming to be recognized as contributing a great deal to certain special fields of lighting. Not long ago small lamps were looked upon as playthings and had little or no commercial application. This was due partly to the limitations of the carbon filament in applications where the cost of supplying energy is necessarily high. With the introduction of tungsten as a filament material, and later with the discovery that drawn-wire tungsten could be coiled into concentrated filaments, an extensive field for miniature lamps was opened. Certain problems in the projection of light were materially simplified by the concentrated filament, and, by the introduction of an inert gas into certain types of these small lamps, greatly-increased efficiency was secured.

Following increased demand came a study of the manufacture of these lamps which is gradually taking them out of the class of hand-made products. The difficulties encountered in cutting and mounting by hand a little piece of wire one-third the diameter of a human hair and, say, 10 mm. in length can be more readily appreciated when it is known that 0.5 mm. in the length of filament in certain types means about 5 per cent. difference in voltage. A number of these miniature lamps now have their filaments coiled and cut by very accurate machines, and a few have semi-automatically mounted filaments.

A growing interest in miniature lamps created higher standards in their application to the fields involved. A few years ago almost any lamp which would give light would suffice; now it is essential that the light shall not only be produced economically, but that every detail of the lamp must be specially designed for the purpose. The dry cell hand-lanterns, for instance, first came into the market with demands that all the light possible should be obtained from a single dry cell, without regard to the life of lamp or battery. These lanterns now replace the old oil lantern, and manufacturers are requiring that the battery and lamp shall receive fully as much consideration as the light produced.

Scrap Cutting Machine. R. G. Skerrett. (*The Iron Age,* vol. 97, No. 10, March 9, 1916.)—R. Philipp, a German engineer, has devised what might properly be termed a mincing machine which cuts into small bits all sorts of metal turnings, and in this way effects

substantial economies that materially improve the market value of this particular kind of scrap. In the first place, he made it possible to save in space something like 80 or 90 per cent., so that the waste materials, when ground up, occupy approximately about one-tenth the room ordinarily needed for turnings as they come from lathes. Owing to its reduced bulk and lowered storage charges it brings better prices from the purchaser. It can be readily freed of oil by means of centrifugal separators, and that iron and steel scrap in this form can be separated magnetically from other scrap material is an advantageous factor in its preparation for further use.

In general design it resembles the common type of vertical conical hopper grinder. If desired, a magnetic separator can be attached. The largest amount of scrap dealt with by one of the Philipp cutters was some 7700 pounds of manganese copper turnings disposed of in 20 minutes. A 25-horse-power direct-current motor was employed. It was found, after a six months' trial, that the entire cost of using the Philipp apparatus did not exceed 32 cents per ton of scrap cut up. But subsequent use proved that the average cost of the service per ton was less than 24 cents.

Road-building Rock Tests. ANON. (United States Department of Agriculture, Office of Information, March 17, 1916.)—Counties or communities intending to build water-bound macadam roads run considerable risk of failure unless they have the rock they are to use tested for hardness, toughness, and binding power. These are the qualities, in the opinion of the engineers of the Office of Public Roads and Rural Engineering, United States Department of Agriculture, which experience has shown to be most essential to the endurance of a road. The use of rock suited to withstand the wear of traffic is regarded as so important that the United States Department of Agriculture offers to test samples of road-building rock for any citizen free of charge, provided that the samples are sent prepaid and are submitted in accordance with definite printed instructions. These instructions will be mailed by the Office of Public Roads and Rural Engineering in that department to whoever requests a copy. When a community is considering using a local stone or other stone which has not already proved its durability on highway work, the highway supervisors would do well to secure a laboratory report from the Department. These laboratory tests are conducted with elaborate apparatus, and, in the case of untried rock, are the only practical safeguards against the employment of material that will wear out too quickly to prove a good investment.

Engineers having to do with road-building material, or road officials contemplating the establishment of a laboratory for testing the rock used on their highways, will find that Bulletin No. 347 contains full details as to the apparatus needed and the exact methods of procedure in the case of their tests, as well as those for determining the specific gravity and water-absorbent qualities of the rock.

Automatic Motor-driven Typewriter for Printing Form Letters. ANON. (*Electrical World,* vol. 67, No. 11, March 11, 1916.)—Form or circular letters, written on the ordinary duplicating machines with the name, address, and salutation " filled in " on the typewriter or from a name-plate, seldom receive the attention from the recipient that a letter entirely written on the typewriter does. The advent, therefore, of an automatic electrically-driven machine which, so far as results are concerned, produces a letter that bears all the marks of one printed by hand should prove of first importance as an office appliance.

A motor-driven typewriting machine, the operation of which is automatic and is controlled by a perforated " master sheet," is being made by the Hooven, Owens & Reutschler Company, of Hamilton, Ohio. A $\frac{1}{20}$-horse-power motor is utilized to operate the automatic mechanism. The master sheets are prepared on a perforating machine, which is equipped with an ordinary standard keyboard. The copy produced is in the form of perforations upon a roll of strong paper similar to the perforated rolls of the player-piano. The complete equipment consists of a standard typewriter of any special type and style desired, to which is connected the automatic operating device, and the perforating machine mounted on a separate stand. The typewriter can also be operated by hand when desired. The machine writes from 100 to 120 words per minute.

Calculation of Skin Effect in Strip Conductors. H. B. DWIGHT. (*Electrical World,* vol. 67, No. 11, March 11, 1916.)—The theory of the alternating-current skin effect of infinitely wide strips was published by Lord Rayleigh nearly thirty years ago, but the experimental observations in the A. I. E. E. paper of Messrs. Kennelly, Laws, and Pierce, last September, seem to have been the first publication of actual measurements on the subject. Those measurements showed that the skin-effect resistance ratios for ordinary sizes of copper strip are many times greater than those to be expected from the theory of infinitely wide strips.

The author collects the observations given in the A. I. E. E. paper, and shows that the skin-effect resistance ratios of these strips, up to frequencies of 5000 cycles, when plotted as ordinates against a certain specific quantity $\sqrt{f/R}$ as abscissas, where f is the impressed frequency and R the tabular linear resistance of the conductor in ohms per thousand feet, gives a curve which rapidly tends to a straight line. The corresponding curve and asymptotic straight line for round wires are already known. It is pointed out that, whereas the curve for round wires represents a definite formula, established both by measurement and by theory, the new curve for strips represents only an empirical result, based on certain concordant measurements, but not established as yet on a definite theory. The curves offered by Mr. Dwight, however, will, within their limitations, be very useful.

A New Process of Refining Nickel. ANON. (*The Iron Trade Review*, vol. lviii, No. 10, March 9, 1916.)—A new process of refining nickel has been discovered in Canada by which 100 pounds of ore can be converted into 50 pounds of metal in 48 hours. Prof. L. P. Burrows is the inventor of this new process, which seems likely to revolutionize the nickel industry. The process is also applicable to the treatment of other ores. By Professor Burrows's method there is no preliminary roasting. The ore, when mined, is crushed and placed in the refining apparatus, where it is subjected to a gaseous treatment for about five hours. After this it is smelted and refined to the finished alloy in the form of a very fine powder, being a very superior article for alloying steel. This powder equals about 75 per cent. of the ore. If desired, the powder can be reduced to the metallic form, producing about 50 per cent. in weight of the ore, entirely free from sulphur and eminently suitable as a high-grade metal for many purposes, as well as for alloying steel. The steel produced by this alloy has proved better than steel produced by a higher percentage of alloy as done by the old method. Professor Burrows has demonstrated that the immense iron deposits of the Laurentian range can be satisfactorily treated, and that the new process will result in the building up of enormous industries in the production of steel, and particularly the world's supply of nickel steel.

The Compressibility of Natural Gas at High Pressures. G. A. BURRELL and I. W. ROBERTSON. (United States Bureau of Mines, Technical Paper 131, February, 1916.)—In the course of its examination of samples of natural gas from many different gas fields through the country the Bureau of Mines has conducted various special researches in order to ascertain with exactness the composition or physical properties of certain of the samples or to determine the bearing of the facts on larger problems involved in the transportation and use of the gas. This paper treats of an investigation of the compressibility, at pressures up to 35.5 atmospheres, of the natural gas supplied to the city of Pittsburgh, and points out the bearing of the results on the measurement of natural gas at high pressures.

The natural gas used at Pittsburgh is found to contain 84 per cent. methane. The compressibility of methane has been determined by Amagat from pressures of 39 atmospheres to 290 atmospheres. From 39 atmospheres (his lowest observation) to 1 atmosphere approximate values have been derived by extrapolation. Methane is about 9 per cent. more compressible at 40 atmospheres and about 17 per cent. more compressible at 100 atmospheres than at 1 atmosphere. The compressibility of the gaseous constituents of natural gas, such as ethane, propane, and butane, has not been determined. These constituents deviate more from Boyle's law than does methane, and hence make natural gas more compressible than if it consisted of methane alone. The compressibility of the natural gas of Pittsburgh

is shown by manometer tests to differ from that of an ideal gas by as much as 15 per cent. at a pressure of 35.5 atmospheres.

The results are of practical value because, in measuring natural gas, it is the practice to assume that the product of the pressure by the volume is a constant. As to the application of these results, it may be noted that sometimes natural gas is measured at pressures as high as 40 atmospheres, and that many millions of cubic feet are measured at pressures of 20 to 30 atmospheres. In computing the volume of gas, the assumption is always made that Boyle's law applies; that is, that the product of pressure and volume is constant at all pressures. Hence, in measurements under high pressure, the error introduced is of great magnitude. For instance, suppose 100,000,000 cubic feet of gas a day are measured at 375 pounds. According to the tests, the gas is 11 per cent. more compressible at 375 pounds than at atmospheric pressure. This means that each day 11,000,000 more cubic feet of gas are measured than are supposed. If no correction is applied in measuring the gas, a distributing company that buys natural gas at high pressure and sells it at low pressure may sell much more gas than it pays for.

The Origin of the Watch. G. F. EBERHARD. (*The Metal Industry,* vol. 14, No. 3, March, 1916.)—We learn from books of record the first watches were made in the year 1500, in Nurenberg, Germany. They were made of iron, all parts, even the dials. Brass was substituted in 1530, and in 1550 watches began to come into vogue. In 1570, odd-shaped watches, hexagon and octagon shape, began to be fashioned. It was not until 1587 that the watch industry began in Switzerland.

The fuzee chain was invented by a Swiss by the name of Gruet in 1590. Up to this time a catgut cord was used. Watch-crystals of glass were first made in 1615. Enamelled dials were first made in 1635. The balance spring (known as the hair-spring) was first made in 1676. It is said they were made from hog bristles, and that is how the name "hair-spring" originated. The minute-hand device was first made in 1687, with its hour and minute wheels and cannon pinion which carries the minute hand. The first keyless watches were made in 1700. The compensating balance was invented in 1749. The duplex escapement was first made in 1750. The lever escapement, now so extensively used, was invented in the year 1776. Second hands were first used in 1780. Thin watches were first made in 1776. It will be noted that all important inventions for making watches were made in Europe.

The difficulty with European watch manufacturers was that one small factory would make wheels, and another staffs, and so on, by hand, with the result that, in some places, 34 small factories would make the 150 parts to be finally assembled, requiring an amount of hand work depending upon the skill of the workmen to secure accurate timekeeping qualities. American watch factories have de-

veloped the manufacture of watches so that all parts, including the cases, are made in one large factory with modern machinery, often specially designed for making the parts as nearly as possible in duplicate and interchangeable.

The first watches were made in the United States by Luther Goddard, of Shrewsbury, Mass., in 1812. He made two watches per week, and after completing about 500 watches he retired from business in 1817. About the same time a small watch factory was started in Worcester, Mass., which soon failed. In 1838 the first watches were made by machinery by James and Henry Pitkin, of Hartford, Conn. They produced about 800 watches and retired in 1841. In 1848 Aaron Dennison commenced to develop machinery, and, with E. Howard, his first watches were put on the market in 1853, under the name of "Boston Watch Company," making five watches per day. In 1854 Dennison moved to Waltham, and the company failed in 1857. In 1859 the Waltham watch industry was reorganized.

Several employees of the Waltham factory removed to Elgin, Ill., in 1865 and established the Elgin watch factory. Later the Rockford Watch Company and the Springfield Watch Company were started by employees who left Elgin. Ambrose Webster, who learned his trade as machinist and toolmaker in the Springfield Armory, Springfield, Mass., notable for fine machinery equipment and for doing accurate work, was for some years foreman in the Waltham factory, beginning in 1857. He left them in 1876 and started the American Watch Tool Company, which company furnished the machinery for a number of watch factories. Some failed in years following, resulting in the establishment of the Hamilton, Deuber, and South Bend watch factories.

A new era in the watch business began in 1890, when Robert H. Ingersoll developed the first guaranteed dollar watch, manufactured at Waterbury, Conn., at a rate of 15,000 per day. The success of the dollar watch led to the manufacture of higher grades. The Ingersoll-Trenton watch factory will soon reach the 1000 per day output of the new Ingersoll Reliance watch.

Aluminum Dust. G. H. CLEVENGER. (*Mining and Scientific Press*, vol. 112, No. 4, January 22, 1916).—In the mining industry aluminum dust is chiefly of interest as a precipitant of the precious metals in the cyanide process. It is also used as a reducing agent wherever a powerful metallic reducing agent is required, as, for example, in the production of carbon-free metals, particularly those difficult to reduce, or in the Goldschmidt process of welding (thermit) for producing *in situ* superheated molten iron or steel. Another use is as a "bronze powder" in the preparation of aluminum paint. Perhaps the most important use at the present time is in the manufacture of various explosives. This was first proposed by Escales, of Munich, in 1899, and in 1900 von Dahmen patented the use of aluminum, magnesium, or other light metal mixed with an oxidizing

agent. Ammonium nitrate was among the first used of such oxidizing agents. This explosive, called "ammonal," has given good results in mining and as a high explosive in shells. It has the advantage of being insensitive and very stable, as indicated by the fact that in Austria-Hungary shells filled with it were found good after ten years. Recently aluminum dust has been added to many other explosives. Other metallic powders, as, for example, magnesium, copper, zinc, iron, silicon, ferro-silicon, certain of the rare metals, and various alloys, are now used for a similar purpose. An example of the composition of a modern high explosive using aluminum dust is as follows: Ammonium nitrate, 45 parts; di- or tri-nitrotoluene, 1905 parts; aluminum dust, 45 parts. The aluminum dust is about 92 per cent. pure.

Aluminum dust is frequently adulterated with powders of other metals, particularly zinc and tin, and, at times, also with mica. The difficulty of manufacture accounts for the relatively high cost of the dust, which, in normal times, is almost double that of the metal in other forms. One method of manufacture involves the production of foil by a special system of rolling or combined rolling and hammering. The perfect foil is marketed in that form, while the imperfect foil, usually constituting 65 to 67 per cent. of the total, is comminuted in two series of special stamp mills, the finished product being separated by bolting and winnowing. The final operation is the polishing of the dust in a special device. Another method is to force gas and air into molten metal while it is setting, accompanied by vigorous mechanical stirring. The granules thus formed are powdered in special stamp mills or ball mills. The finely-ground dust is separated and polished as previously mentioned. In all the methods of making aluminum dust it is necessary to add stearine or some other wax to prevent the welding together of the fine particles during crushing.

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OUR EARTH A GREAT MAGNET.*

BY

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Our Earth a Great Magnet! This dictum was first pronounced upon the unsuspecting Earth by the immortal William Gilbert, sometime body physician to Queen Elizabeth. Of him, the "father of magnetick philosophy," Dryden predicted:

> Gilbert shall live till lodestones cease to draw,
> Or British fleets the boundless ocean awe.

In his famous treatise on the magnet, published in 1600, Gilbert summed up the knowledge which he had gained from laborious magnetic researches in the following words: "*Magnus magnes ipse est globus terrestris*" ("The terrestrial globe itself is a great magnet"). Three centuries have elapsed since then, and we can only say: If the Earth is not a magnet, it certainly acts like one.

The Earth a Great Magnet! Our Earth we think we know something of—but *what is a magnet?* To get our subject fairly launched we at least must know what we are going to talk about. Clear vision demands clear definition. "A definition is the resolu-

* The Annual Lecture of the Carnegie Institution of Washington for 1915; given before the Trustees and their guests at Washington on December 9, 1915. Basis of a lecture on "The Earth a Great Magnet," given by the author at The Franklin Institute on October 21, 1914.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

tion of a complex idea into the simple elements which compose it." First of all, then, patterning after Gilbert, we must declare, in familiar language, what are the apparent common virtues of a magnet; afterward numerous subtleties are to be laid upon, by fitting terms and devices; we shall even penetrate, if we can, to the very interior of the magnet's "wizard cell." To do this, let us begin with the natural magnet, or lodestone, a blackish-looking mineral, known to the geologist as magnetite, a specimen of which from Magnet Cove, Arkansas, I hold in my hand. Three centuries ago this stone was so highly prized that it was often used as a setting in rings. Sir Isaac Newton, for example, exhibited with considerable pride a particularly powerful bit of lodestone set in a ring.

EARLY MAGNETIC DISCOVERIES.

The earliest speculations with regard to the nature of the lodestone, or magnet, were those of the early Greeks, in whose philosophy the magnet played an important part. The "father of philosophy," Thales of Miletus, who lived some twenty-five centuries ago, is said to have been the first to disregard the old belief in outside supernatural influences, and to have sought for the cause within the thing itself. He assumed the magnet to have a "magnetic soul, or a virtue," inherent in itself, whereby it could move the "beloved iron." Very naturally this led him to the idea of the soul within man.

Later Plato, another Greek philosopher, having had his attention drawn to the experiment of the "Samothracian rings," performed by the early iron-workers in Samothrace, came to a similar conclusion. "There is a divinity," he says, "moving you, like that in the stone which Euripides calls a magnet, but which is commonly known as the stone of Heraclea. For that stone not only attracts iron rings, but also imparts to them similar power of attracting other rings; and sometimes you may see a number of pieces of iron and rings suspended from one another, so as to form quite a long chain, and all of these derive their powers of suspension from the original stone. Now this is like the Muse who first gives to men inspiration herself, and from those inspired, her sons, a chain of other persons is suspended, who will take the inspiration from them."

Seeing then the part played by the magnet in the old Grecian philosophy, we must not be surprised, since philosophy has ever

permeated and influenced the world's writings, that the magnet has also left its impress upon literature. Thus "in the love of the magnet and the iron a new metaphor is given to the world which even the greatest of its poets has not disdained to use," and in quotations from famous writers we readily find clues to all the chief properties of the magnet. Says Plutarch, for example, "Like as iron drawn by a stone often follows it, but also often is turned and drawn away in the opposite direction, so also is the wholesome good and regular motion of the world." This quotation will serve to emphasize to us the dual property of the lodestone —that of drawing unto itself the all-conquering iron, and that of repelling substances which are in a "magnetic" condition (observe I am still using words before having defined them). This dual property of the lodestone, as just shown you, is called the property of polarity.

As time went on men surrounded the mystery of the magnet with greater mystery. Chief among the fables which sprang up was the long-believed one of the Magnetic Mountains, which Ptolemy located in the China Sea, on islands which he called the Manioles. He says that ships going too near them are stopped, and hence must be put together with wooden nails, in order that the Heraclean stone, which grows there, may not attract them. (Here we have the legendary ancestors of the non-magnetic ship *Carnegie.*) The idea of magnetic mountains, while at the time fanciful, has some basis in the fact that widely distributed over the Earth there are regions of intense local attraction of the compass, generally ascribed to magnetic iron deposits. The isle of Bornholm, in the Baltic Sea, where the American cotton ship *Evelyn,* a few years ago, met her fate, is an intense centre of local attraction of the compass.

One of the new terms occurring in Gilbert's book, which by the way was originally published in Latin, was *coitio,* a coming together. By this word Gilbert wished to convey the idea of action and reaction, later enunciated more clearly by Newton. Thus it was not simply the iron that was drawn to the stone, or, as you have just seen, the iron filings to the magnet, but also the stone or magnet to the iron. Sir Thomas Browne picturesquely expressed this idea thus:

"If in two skiffs of cork, a Lodestone and Steel be placed within the orb of their activities, the one doth not move the other

standing still, but both hoist sayle and steer unto each other; so that if the Lodestone attract, the Steel hath also its attraction for in this action the Alliency is reciprocate, which jointly felt, they mutually approach and run into each other's arms."

The oft-quoted expression, "True as the needle to the pole," which first occurred in a poem by Barton Booth, about two centuries ago, will serve to indicate another striking fact regarding the magnet; namely, if it be mounted so as to turn freely about a vertical axis, after repeated vibration to and fro, it finally settles down in a definite direction, as shown by the lodestone you see suspended. Displace it, and it returns to the same position as before. The direction so persistently assumed is approximately north and south—not exactly so; and here our poetic quotation as to the needle being true to the pole—geographic pole—is somewhat at fault.

We do not know just when this *directive property,* or *property of directivity,* of the natural magnet was discovered, or at what time man learned the art of making artificial magnets. According to early legends, the Chinese had made use of the directive property of the magnet in land journeys and in the orientation of buildings and sites, long before it had become known, in about the twelfth century A.D., to the people of the Occident.

And now permit me to call attention to the origin of the word "lodestone"; it comes from the Icelandic verb "leid," meaning to lead or point somewhere, or from the Anglo-Saxon "ladman," a leader. The term "magnes" may have originated from the name of the discoverer of the natural magnet or from the city, Magnesia, in Ionia, Asia Minor, where it "grew."

Though we have not as yet defined what a magnet is, we have become familiar by quotation and experiment with its three fundamental characteristics: (1) property of attraction; (2) property of repulsion and polarity; (3) property of directivity—the magnet attracts, it repels, and it points in a certain direction.

BIRTH OF THE SCIENCE OF TERRESTRIAL MAGNETISM.

But so far we have been dealing with the magnet in its simplest form. We come now to a consideration of a far greater and more complex magnet—our Earth. It was while endeavoring to explain the directive property of the lodestone, or of the magnetized needle, that Gilbert reached the hypothesis that the Earth itself is a great

round lodestone. His experiments, on which it is said that he spent £5000, had shown that only a magnet could act on another magnet in the manner revealed by the compass needle.

Since Gilbert's time, however, we have learned that the production of magnetic effects does not necessarily depend upon a substance like the lodestone. Oersted, a Danish physicist, discovered, in 1819, that a compass needle tends to set itself at right angles to a wire carrying an electric current. This discovery gave birth to the science of electromagnetism, and taught us a new way of making a magnet—the so-called electromagnet, of which you have a specimen before you.

From Oersted's experiment we know now that the Earth need not be a great lodestone to be a magnet, or act like one. Thus electric currents circulating within the Earth, approximately at right angles to the compass direction, or from east to west, would have the same effect. Were we to attempt to make at present any improvement on Gilbert's hypothesis, we should say that the Earth is either a great magnet or a great *electromagnet*. But still we have not as yet defined a magnet, nor, for that matter, an electromagnet. However, observe that we are engaged in the execution of that simple process referred to at the beginning of the lecture—the resolution of the complex idea of a magnet into its simple, constituent elements.

THE EARTH'S MAGNETIC LINES OF FORCE.

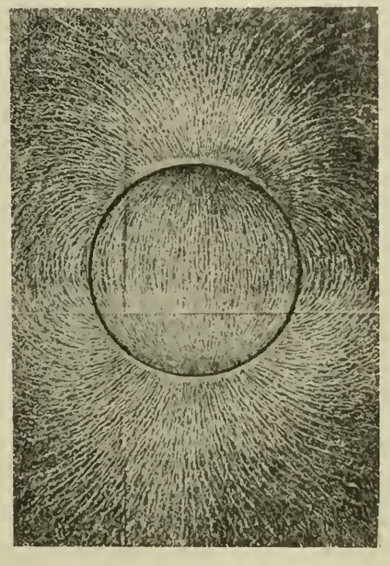
To assist him in the interpretation of magnetic and electric phenomena, that skilful investigator, Michael Faraday, introduced, a century ago, the happy terms, "magnetic field" and "magnetic lines of force." These concepts, in some form, though vague, had already been in the minds of the early writers. Thus Robert Norman, who discovered the dip of the magnetic needle in 1576, says, in his memorable book, "The Newe Attractive": "And surely I am of opinion that if this Vertue could by any means be made visible to the Eye of man, it would be found in the sphericall forme, extending round about the Stone in great Compasse, and the dead bodie of the Stone in the middle thereof."

On the screen you have projected the image of a bar magnet. Let us see what happens when there is brought near it some iron filings. See how the tiny filaments gradually arrange themselves around the magnet in a beautiful series of curves, which start and

end at certain points, called the poles. Look at the filaments; what is controlling them? How fondly the magnet holds them in its embrace! Is it then surprising that the lodestone was also called the lovestone, a meaning still preserved by certain countries in their names for the magnet? Thus the French still call the magnet *l'aimant,* or the loving one.

If every magnet is surrounded by lines of force, such as have just been traced out for us on the screen, then, since the Earth

FIG. 1.



Magnetic lines of force as they would envelop the Earth if its magnetic axis were coincident with its axis of rotation. [The Earth's magnetic poles are, on the average, about 1200 miles from the geographic poles, and they are not diametrically opposite each other. A straight line connecting the magnetic poles would pass through the Earth 750 miles distant from the centre.]

acts like a magnet, it also must be enveloped by magnetic lines of force. The picture next seen on the screen (Fig. 1) shows how these lines of force would envelop the Earth were its magnetic axis coincident with the axis of rotation, instead of inclined to it. We see that the lines of force enter the magnetized sphere at various angles of inclination or dip, the steepness diminishing steadily from the poles to the equator. The next slide (Fig. 2) will give you some idea of the irregularity of the actual magnetization of the Earth.

To demonstrate the existence of the Earth's magnetic lines of force passing through this room, through your body and through mine, we will make use of the discovery which founded the branch of electrical science known as magneto-electricity. The operator is holding in his hand a coil of copper wire connected with a galvanometer, from whose mirror a spot of light is now thrown on the screen; note that the spot is standing at a certain number of the scale above it. He now moves the coil so that it cuts across the lines of force of the electromagnet near by. See the sudden movement of the spot of light!

Using a similar coil, let him next give it a quick turn in the

FIG. 2.

The North Magnetic Pole is about in latitude 70° north and longitude 97° west, and the South Magnetic Pole is about in latitude 72° south and longitude 153° east. [The irregularity of the Earth's magnetization is also shown by the departure of the magnetic equator from the geographic equator. The arrows show how a dipping needle would point in different parts of the Earth.]

Earth's magnetic field. Observe that the spot of light again moves. The largest movement is observed when the coil is turned with its axis at right angles to the magnetic lines of force of the Earth. And if the operator turn the coil so that its axis is parallel to the terrestrial lines of force, there would, eventually, be no movement of the spot.

The cause of the movement of the spot in both experiments was the generation of a current of electricity by the rotation of the coil in the magnetic field. In the first experiment the magnetic field was that around an artificial magnet; in the second experiment it was the Earth's magnetic field.

You have thus had demonstrated to you the existence of a magnetic field surrounding the Earth, and have also been shown the principle on which one instrument, the so-called earth inductor, for measuring the dip of the magnetic needle, depends (see Fig. 9, B).

HOW STRONG A MAGNET IS THE EARTH?

If the magnetism of the Earth were uniformly distributed throughout its volume, then the magnetic intensity of each cubic yard would be equal to six one-pound steel magnets, like the one I hold in my hand, which is fourteen inches long, one inch wide, and one-quarter inch thick. However, at a depth of ten to twelve miles below the surface, the temperature would be so high that magnetized substances could not exist, for heat destroys magnetism. Hence, if the Earth's magnetic phenomena are caused by magnetized materials, they probably would have to be confined to the outer ten-mile layer of the crust, and the average magnetic intensity per cubic yard would be equal to more than that of six one-pound magnets.

Suppose there were no interior heat and that we could concentrate our one-pound magnets all at the centre of the Earth, with their magnetic axes all parallel to the Earth's magnetic axis, how many would be required to cause magnetic forces on the Earth's surface such as we actually measure? Only eight thousand five hundred million million millions! Place these 14-inch magnets in line, end on, and they would reach to a point in space distant from us twenty thousand million times that of the Sun from the Earth, or about seventy thousand times that of the nearest star, Alpha Centauri, whose light requires four years to reach us. As you know, light travels one hundred and eighty-seven thousand miles per second. Looked at in the way just stated, the Earth appears to us a very strong magnet, indeed.

By modern methods we could magnetize a bar of specially-prepared steel so that it would be four and one-half times stronger than the specimen used for illustration. The average intensity of magnetization of the Earth's substance, for the entire volume, would be only about 1/10,000 that of very highly magnetized steel. This fact led Professor J. A. Fleming to remark: "Taken as a whole, the Earth is a feeble magnet. If our globe were wholly made of steel and magnetized as highly as an ordinary steel-bar

magnet, the magnetic forces at its surface would be at least one hundred times as great as they are now. That might be an advantage or a very great disadvantage."

FIG. 3.

The non-magnetic yacht, *Carnegie*, setting out on her cruises in 1909. [In October, 1909, she followed practically the same track from St. Johns, Newfoundland, to England, as that of Halley's ship, the *Paramour Pink*, in 1699.]

CHANGE OF EARTH'S MAGNETISM WITH TIME.

In the year 1634, Gellibrand, professor of mathematics at Gresham College, England, found that at London the north end of the compass pointed only a trifle over 4° east of north, whereas,

fifty-four years before, in 1580, it had been pointing as much as 11¼° east of north. In 1658, the year of Cromwell's death, the compass pointed truly north and south; in 1812 it pointed 24° west of north, and now it points only about 16° west of north. There is thus made apparent not only the need of magnetic surveys, but likewise their repetition, from time to time, in order to obtain the data for the revision of magnetic charts.

Another striking illustration of the amount of change in the Earth's magnetism with the lapse of time is the following one: In the year 1698 the ship *Paramour Pink* set sail from England, under the command of the noted astronomer, Halley, whom you may recall from the comet named after him. The prime purpose of this expedition was to find out, for the use of mariners, how the compass direction varies over the Atlantic Ocean. Two centuries later another sailing vessel, the *Carnegie* (Fig. 3), sailed from Newfoundland, to carry out the same task begun by Halley, but this time on a more systematic, comprehensive, and accurate basis. Had the *Carnegie* followed the same magnetic courses across the Atlantic as were held by the *Paramour Pink,* instead of coming to anchor at Falmouth Harbor, on the English Channel, the *Carnegie* would have made a landfall somewhere on the northwest coast of Scotland!

Some of the best minds have been engaged in trying to discover the cause of the mysterious change of the Earth's magnetism, but the problem, in its entirety, is still unsolved. Both as regards the actual motions of the Earth's magnetic poles with the lapse of years, and the precise cause or causes thereof, we may still say with Halley that these are "Secrets as yet utterly unknown to Mankind, and are reserv'd for the industry of future ages."

WHAT IS A MAGNET?

We are now through with the serious part of the lecture. Having resolved the complex idea of "magnet" into the simple elements composing it, and having familiarized ourselves with the chief characteristics as represented by magnets of various kinds—the lodestone, the bar-magnet, the electromagnet, and even the Earth-magnet—the rest is easy, and we can immediately give the answers to our questions: What is a magnet? What is magnetism? and What is a magnetic field? We are peculiarly

fortunate in that we may avail ourselves of the definitions of the most eminent astronomer of his time. In the latter years of his life he sought the aid of magnetism to solve some of the great outstanding problems of astronomy—the irregularities in the motions of the Moon, for example, which apparently could not be explained on the gravitation theory alone. I refer, of course, to the late lamented Simon Newcomb.

Professor Newcomb was given general oversight of the definitions in physical science for a certain dictionary. Taking exception one day to the definitions for magnet and magnetic force submitted to him, he was requested by the assistant editor to try his hand at framing better definitions. After alternately writing and erasing for an hour or more, the astronomer, with a hearty laugh, handed in the following definitions: "*Magnet:* a body capable of exerting magnetic force; *Magnetic Force:* the force exerted by a magnet!"

Could you imagine any more satisfying definitions? Yet to show you how inappreciative literary folk are of exactness in science, I have but to cite you a quotation from Ambrose Bierce's Cynic's or Devil's Dictionary. Here we find the following definitions: "*Magnet:* n.—Something acted upon by magnetism; *Magnetism:* n.—Something acting upon a magnet." Bierce then cynically remarks: "These two definitions are condensed from the works of 1000 eminent scientists who have illuminated the subject with a great white light, to the inexpressible advancement of human knowledge."

Alas! it is only too true that, in spite of centuries of research, we can not as yet say precisely what magnetism really is, nor do we know exactly by what physical process a substance is put into the state we term "magnetic." But, for that matter, can any one tell us precisely what electricity is, or even what is the force of gravitation? In this connection, the cynic above quoted says: "Newton discovered that an apple will fall to the ground, but was unable to say why; his successors and disciples have advanced so far as to be able to say when." Indeed, it is questionable whether Man, whom a German philosopher named "*das Ursachenthier*"—the animal ever incited and stimulated by his inquisitiveness to search out the cause of things—will ever be able to determine the ultimate causes, or, shall we say, the cause or origin of Nature's primal forces. But let that not discourage us. Have we not,

each one of us, at some time or another, felt the truth of Robert Louis Stevenson's words:

> To travel hopefully is better than to arrive,
> And the true success is labor.

Let us then arouse ourselves, and, like "true philosophers, ingenuous minds," leave now our books and indoor experiments, and go out and deal with things as revealed by Nature at large with respect to the great magnet, our Earth.

In doing this, let us ever keep in mind that this great Earth of ours is not bounded by the surface we tread, nor even by the

FIG. 4.

The Aurora Borealis as first photographed by Professor Carl Stoermer.

farthest atmospheric levels above us; that there is besides a *something,* inseparably bound up with the Earth, extending far out into illimitable space, exceedingly tenuous and ordinarily invisible, except when made apparent to us by the beautiful phenomenon of polar lights, whose flickering lights and shooting rays arrange themselves in accordance with the Earth's magnetic lines of force, and "dance in rhythm with the quivering needle" (Fig. 4). As has been well said: "Our globe, as it spins through space, is clothed, as it were, in a gossamer garment woven of lines of magnetic force, and this little trembling needle serves as a sensitive finger, whereby we track out the path of these invisible clues, and, confidently determining our direction, though wandering over

wide waters, wrapped, it may be, in darkness or in storm, are enabled thereby to establish a continual intercourse between all portions of the globe."

THE COMPASS IN NAVIGATION.

An old seafaring man from down East, when asked how he managed to get about, having never studied navigation, naïvely replied: "I know 'nough navigation to git out o' Boston harbor, and then I ken go where I durn please." Most of us are not in the fortunate position of this happy mariner who can go where he pleases. When you or I take an ocean liner we usually must go to some definite place, and we regard our good captain as not proficient if he does not succeed in getting us there safely by the most direct path and in the quickest possible time. What does this imply? Our palatial ship is strongly built of most durable steel, every modern electrical contrivance known to man is at our command, we are being impelled through the seas by the most powerful steel engines of the time, we have besides our cargo of precious human freight a great amount of merchandise, consisting, perhaps, of masses of iron and steel. As we stroll the hurricane deck on a sunny day we note how eager are the ship's officers (Fig. 5) to get their sights on the Sun for determining both the ship's position and the course to be followed to our invisible port far beyond the horizon. What serves to guide the helmsman in holding the ship's course during the intervals between these astronomical observations, or what will the mariner do if clouds and rain obscure Sun and stars?

> No ship could sayle on seas,
>   her course to runne aright,
> Nor compass shew the ready way,
>   were Magnes not of might.

So says Robert Norman, in 1581, in his quaint poem, entitled, "The Magnes' or Lodestone's Challenge."

If, then, in spite of the "constant inconstancies of the magnetical needle," and the use of every modern contrivance, the mariner must still rely chiefly on the compass to guide him across the trackless seas, and the explorer must depend on the needle to direct him through the deep jungle and over the arid wastes, how important it is that this compass should be true and that the "vagaries of the needle" should be definitely known.

The falsifier of the compass today is not the sailor with the garlic breath, as was the belief four centuries ago, but our steel ship and the iron and steel carried on board. Magnetism acts

Fig. 5.

Sextant observations aboard the *Carnegie* on her trip to Spitzbergen in 1914. [Even when the vessel is rolling as much as shown in this view it is possible, with the special appliances used, to make good magnetic observations.]

freely through wood, brass, and many other substances, but when a piece of iron or steel is interposed the Earth's magnetic lines of force are displaced or altered to such an extent that a compass

nearby may be seriously affected. So our ship is itself a magnetic body, and our standard compass points in the direction as determined by both the Earth-magnet and the ship-magnet.

Unhappily, also, the ship's magnetism varies both in direction and strength as our vessel travels from port to port; it varies with the course, and with the buffeting of the waves against the ship's sides. The skilled mariner must be ever on the alert and must know how to reduce the errors of his compass to the smallest amount possible, in other words, apply correcting or compensating devices, and then constantly control the outstanding error by observation. To do all of this successfully, he must first know what direction the compass would point were his ship not a magnet. As he can not reconstruct his vessel, he must instead have a chart which will show him for every place over the oceans traversed what the correct compass direction is. The securing of the data for such a chart is the special object of the vessel of which many of you have already heard. This illustration must serve, for time is fleeting, to bring home to you at least one of the objects of magnetic surveys.

The idea of making such a magnetic survey of the Earth is not a new one, but never before has it been possible to accomplish it on the scale and within the time that the work is being done under the auspices of the Carnegie Institution of Washington. After the initial work in the Pacific Ocean, 1905–1908, on the chartered vessel the *Galilee,* it was decided to construct a vessel specially adapted for ocean magnetic surveys—a non-magnetic ship.

THE "CARNEGIE."

And thus we come now to a brief recital of the work of the non-magnetic yacht, the *Carnegie,* a picture of which you see on the screen (Fig. 6). Note her graceful lines and sturdy appearance! Having weathered many a severe gale, this vessel is possibly the best known craft afloat; if not, she is certainly, as one of our magazines has declared, the most *unattractive* one. Her length is but 155 feet over all, her beam is 33 feet, her tonnage is less than one-hundredth of that of the modern ocean greyhound, yet she has achieved a record during the six years of her existence of which her owners—the Carnegie Institution of Washington—are proud. Her voyages have extended from the parallel of 80°

north, off the northwest coast of Spitzbergen, to New Zealand. She has travelled the "seven seas" and has encompassed the Earth seven times, with scarce a mishap and no loss of human life by accident or negligence. It would seem that it is safer to bunk aboard the *Carnegie*, in one of her cosy, non-magnetic beds, than to repose in magnetic slumber in the most comfortable bed ashore!

The *Carnegie* is built of wood, bronze-fastened, and is rigged

Fig. 6.

The *Carnegie* at Bahia, Brazil, in May, 1913, dressed in honor of the port holiday. [One of the two special observing domes is seen just abaft the foremast.]

with hemp, all metal work on the spars being of bronze and gun-metal. Even the anchors, of which there are four, aggregating 5500 pounds, are of bronze. The usual chain cables are replaced by hemp, as was the common practice some hundred years ago. To carry out the idea of a non-magnetic ship, we had to revert to old practice in some other details. For example, a fisherman's windlass, of a type still seen on fishing schooners, is used to weigh

anchor by a pumping action. The cooking ranges and refrigerating plant are of bronze and copper, and the cutlery is of Mexican silver.

The only iron and steel on this unique vessel is that entering into certain parts, the pistons and cams chiefly, of the auxiliary power, a producer gas engine. But the total mass of the magnetic material is only about 600 pounds, or 3 per cent. of the total weight of the power plant. Its distance from the nearest instrument used in the magnetic observations is such as to cause no observable effect.

FIG. 7.

The personnel of the *Carnegie* usually consists of the commander, who is in charge both of the observational work and of the vessel; 4 observers, 1 clerk, 3 watch officers, 1 engineer, 1 mechanic, 8 seamen, 2 cooks, and 2 cabin boys—23 persons in all. [The after dome, or observatory, is shown on the left.]

Among the special features are two revolvable glass domes (see Figs. 6 and 7) which form the observatories in which the magnetic observations are made, the observers (Fig. 7) and instruments being thus completely sheltered from wind and weather. In addition to the magnetic work, observations are made in

atmospheric electricity, and also for the determination of the amount of atmospheric refraction.

The *Carnegie's* speed is, in general, a leisurely one in comparison to that of a modern liner, about 100 to 150 miles a day, this being the average distance apart of our magnetic observations. Still, with a fair wind about 200 to 300 miles may be the *Carnegie's* daily run. The passage from St. Johns, Newfoundland, to Falmouth, England, in 1909, was made in eleven days. The *Carnegie* rides the boisterous waves up and down like a duck, instead of butting through them as does the ocean greyhound; she may thus have dry decks when the larger vessel is being continually drenched.

Let me then invite you to take a trip on the *Carnegie* from New York to Colon, next through the Panama Canal to the Pacific Coast, so that by personal observation you may become familiar with her work and her personnel.*

ERRORS OF MAGNETIC CHARTS.

A word as to the errors found in the magnetic charts heretofore in use for navigational purposes and scientific investigations. In the Pacific and Indian Oceans, where reliable information was especially scanty until the magnetic data of the Carnegie Institution of Washington were obtained, the errors in the compass direction, as given on the mariners' charts, were from 1° to 5°. The errors, unfortunately, were frequently in the same direction for stretches of 1000 miles and more. Thus, for example, on the 2000-mile run from San Francisco to Honolulu, the effect of the compass-chart errors, averaging from 1° to 2° always in the same direction, was to set the ship's course ever to the northward of that intended. Thus the vessel at the end of a week's voyage, during a cloudy spell, when the course could not be controlled by Sun or stars, might be found about thirty miles to the north of her intended landfall.

Matters were even worse on the run from Colombo, Ceylon, to Mauritius, in the Indian Ocean, where the compass-chart errors reached 6°. Peculiar experiences had been reported at various times with regard to the apparently rapidly-changing magnetic

* Here motion pictures were shown, as taken on the *Carnegie's* 1915 cruise, from Brooklyn to Balboa, Canal Zone.

deviations, or ship's magnetism, during this passage. The *Carnegie* observations of 1911 showed that it was not rapidly-changing magnetism of the modern steel ship that was the cause of these peculiar experiences, but the systematic and cumulative errors made in basing the ship's courses on the charts then in use.

Similar errors, though not quite so large, for the Atlantic Ocean, were disclosed on the *Carnegie's* trip from Brooklyn to Falmouth, England, in 1909. There had been repeated reports by reliable navigators that some peculiarity existed off Cape Race, Newfoundland, which caused an abrupt change in the ship's magnetic deviations. It was shown indisputably by the *Carnegie* observations that the fault was to be ascribed not to any pronounced peculiar magnetic conditions in the ocean, off Cape Race, but to the peculiar distribution of the errors of the mariners' magnetic variation charts. The chart errors were of opposite sign on the two parts of the voyage, New York to Cape Race, and Cape Race to the English Channel. The effect was always to set the ship's course towards the rock-bound Newfoundland coast, no matter whether the ship came from the east or from the west.

Errors in the magnetic dip charts have been found as great as 6.5°, and in the charts giving the strength of the magnetic force acting on a compass needle as great as one-tenth of the quantity.

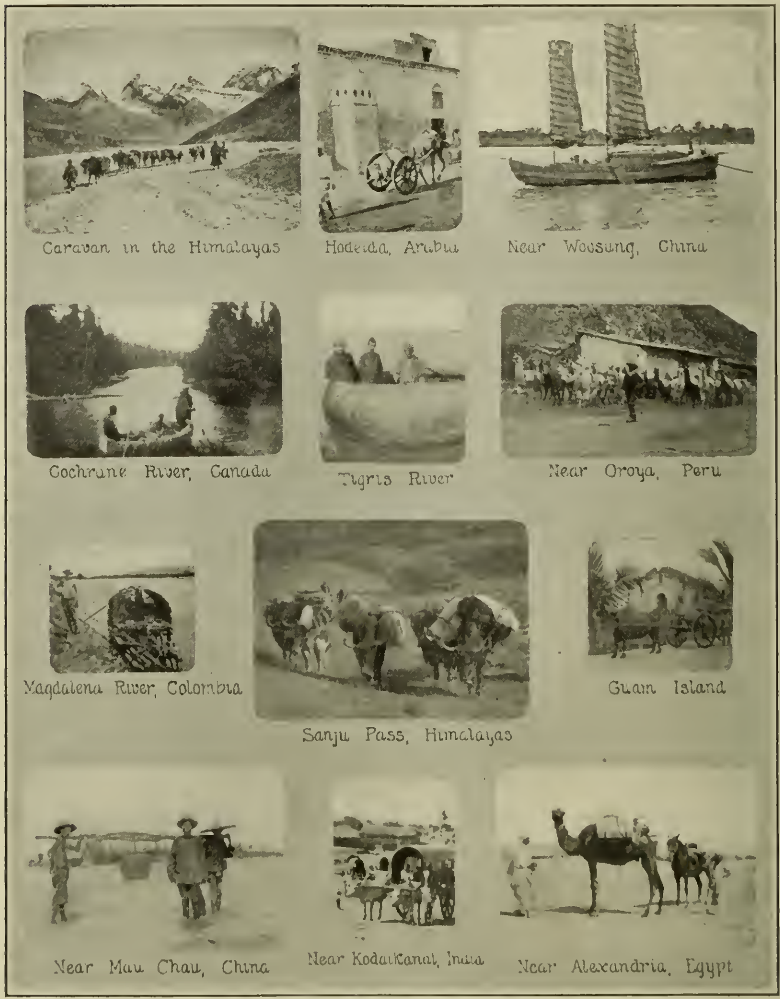
PROMPTNESS OF PUBLISHING DATA.

From the start of our work it has been the aim to profit by the experiences of previous expeditions. Well-nigh invariably, the magnetic data obtained could not be made known publicly until many years after the close of an expedition. By such delays the collected data lost much of their utilitarian value.

We therefore endeavor to supply the leading hydrographic and scientific establishments of various countries promptly with our results. This aim has been accomplished to such an extent with our facilities—a non-magnetic ship, specially-devised instrumental appliances, well-trained observers, and computers—that we can furnish the data of chief interest in navigation within two months, on the average, after the observations were made at sea. Thus the results of the observations for compass direction obtained on the *Carnegie* on her passage in July, 1915, from Honolulu to Dutch Harbor, Alaska, were received at the Office of the Depart-

ment in time to be sent out to the chief hydrographic offices engaged in the construction of magnetic charts by the end of August,

FIG. 8.



Typical views of land magnetic survey expeditions in various regions of the Earth.

1915—hence, in this instance, but one month after the close of the series of observations.

LAND SURVEYS AND STATUS OF MAGNETIC SURVEY OF THE EARTH.

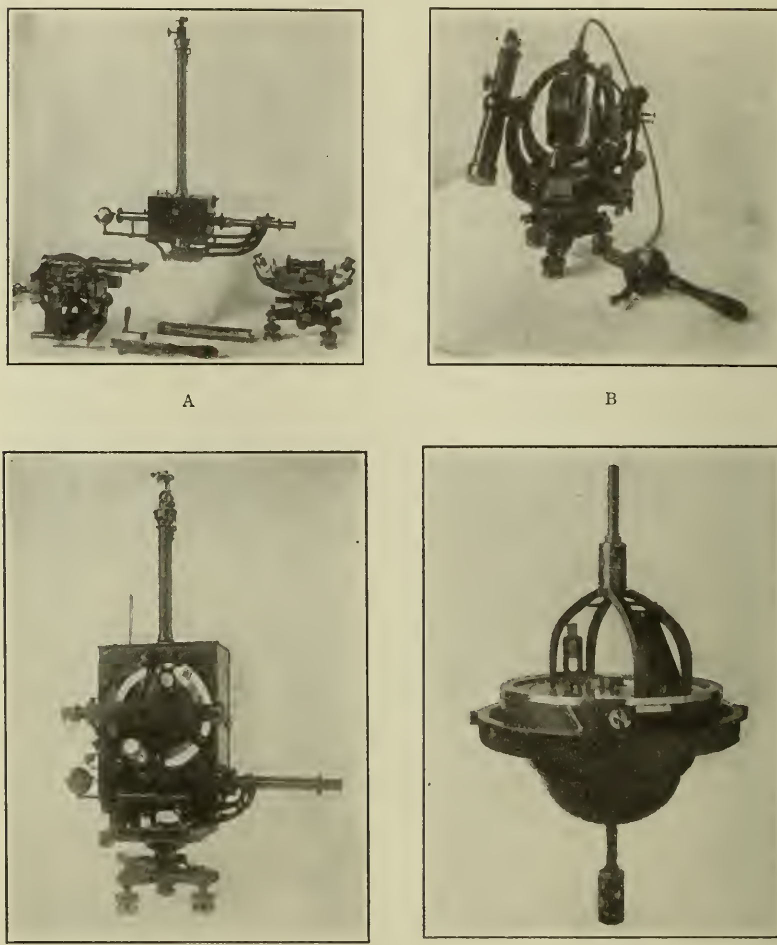
A few typical views (Fig. 8) must suffice to illustrate the travels of our land expeditions, which, in many respects, are no less worthy as regards meritorious achievement than the work of the unique vessel just described. We might easily fill the evening with a recital of some of the experiences encountered in the course of these expeditions, which, during the eleven years' existence of the Department of Terrestrial Magnetism, 1904–1915, have penetrated nearly every region of the globe, and have been achievements in geographic exploration as well as in our special science. There have been fifty of these expeditions in about one hundred and twenty different countries. Fully a million miles have been traversed, or a distance forty times around the Earth or five times the distance of the Moon from the Earth. The stations at which the magnetic elements have been measured number about 3300 and extend from the Arctic to the Antarctic. Among notable expeditions may be mentioned the complete crossings of China, Australia, and South America, east to west and south to north; the Trans-Saharan expedition from Algeria to Nigeria; extensive canoe expeditions in the interior of British North America to more or less unexplored regions, and to Hudson Bay; hazardous coastal trips in Africa and Central America; difficult interior trips in Asia Minor, Persia, and various countries of Africa and South America, etc.

It is pleasing to note here the interest taken in the work the world over, as evidenced by the cordial coöperation received in return for that extended to foreign nations. Thus the following resolution was passed at the St. Petersburg meeting of the International Association of Academies in May, 1913:

"The committee, in view of the work of making a magnetic survey of the globe, particularly on the oceans, undertaken by the Carnegie Institution of Washington, resolves that it is of the highest importance that similar work be completed as soon as possible, in those countries where no surveys exist or where they have been made at epochs relatively distant from those of the Carnegie Institution of Washington.

The next slide (see map) exhibits the status of the magnetic work of the Carnegie Institution of Washington on land and ocean, from 1905 almost to the close of 1915; as you see, it shows the large extent of work accomplished. Nearly all parts of the

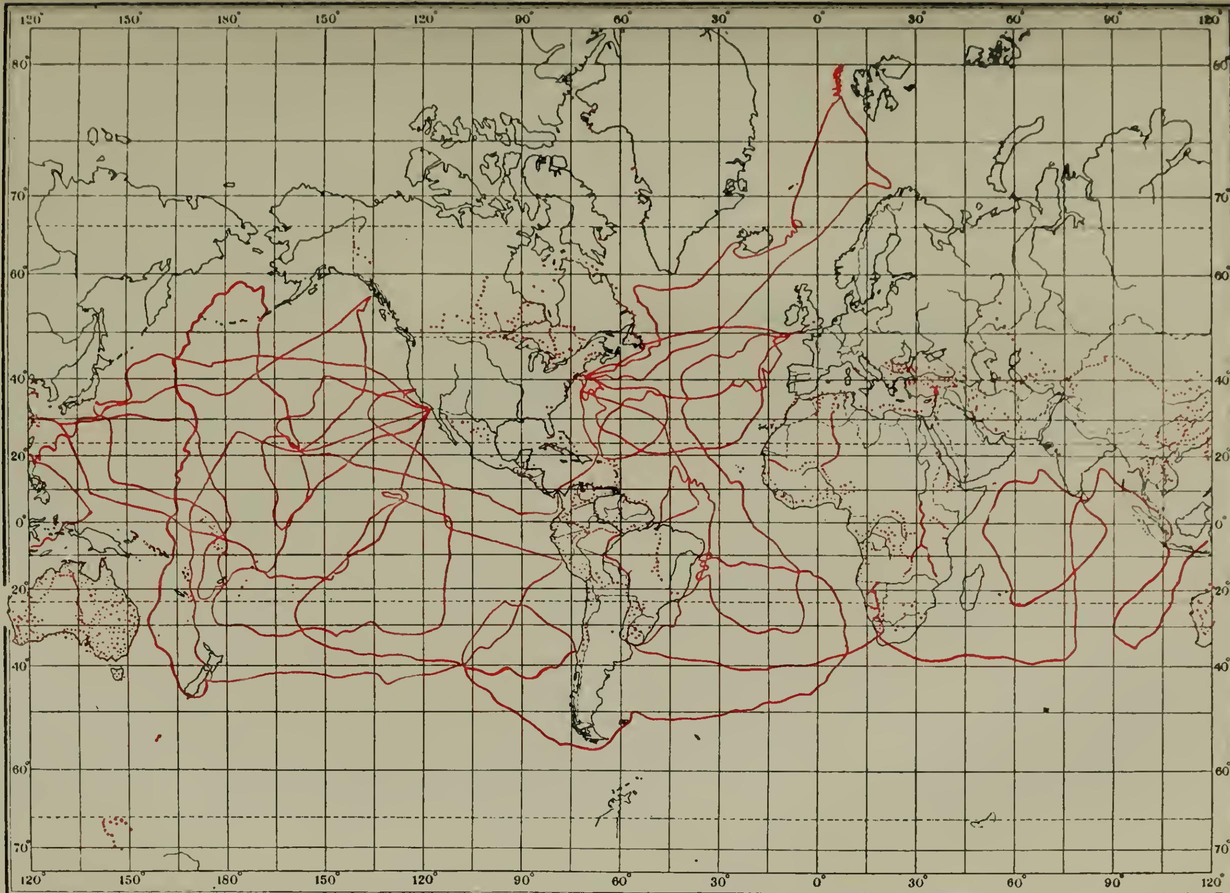
FIG. 9.



A B C D

Views of some of the instruments used in magnetic survey work, designed and constructed by the Department of Terrestrial Magnetism. A. Magnetometer-inductor. B. Earth inductor used both on land and at sea for measuring the magnetic dip. C. Universal magnetic instrument for measuring all the magnetic elements and for the determination of geographic position; especially designed for difficult land expeditions requiring a light and compact type of instrument. D. Deflector used on the *Carnegie* for measuring the horizontal intensity of the Earth's magnetic force, and the magnetic declination.

Earth have now been covered with magnetic surveys. On December 6, 1915, the *Carnegie,* as in 1914, under the command of Captain J. P. Ault, left Port Lyttelton, New Zealand, for a cir-



THE MAGNETIC WORK OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, 1905–15 (NOVEMBER)

cumnavigation of the regions between the parallels 50° and 60° south, where practically no magnetic data have been obtained during the past seventy years. [The *Carnegie's* arrival on January 12, 1916, at South Georgia Island was reported; she sailed again on January 14, and arrived at Port Lyttelton on April 1.]

It is impossible to refer to the work of the observers individually in calling attention to the devotion, zeal, enthusiasm, and ability displayed in the successful accomplishment of duties well performed, at times under most adverse circumstances; in strange countries, amidst strange people with strange customs and speaking a strange language; often over infrequently traversed roads, and even at times in regions either rarely or never before, so far as known, reached by the white man; pursuing the work faithfully, even when revolution was rife in the countries visited and travel was attended with many dangers; following steadfastly in the direction of their goal at no little sacrifice of personal comfort and even sometimes at the risk of life and limb. Not only was meritorious work accomplished, but, owing to their care and good judgment, the entire work was executed without a single loss of life.

The instruments (Fig. 9) used in the work on land and at sea have been largely designed by the Department of Terrestrial Magnetism, and constructed in its own workshop. Some of the instruments have been duplicated for foreign countries.

ASTROMAGNETISM.

I was introduced once as the Director of the Department of Astromagnetism. This incident may serve to lead to our concluding query: Is the Earth the only member of the Universe surrounded by a magnetic field?

Some of you doubtless have had the good fortune to see, during a total solar eclipse, the soft, pearly light which surrounds the Sun and extends far out into space. The streamers of this beautiful phenomenon, especially during a period of minimum sun-spot activity, appear to curve towards the Sun's poles in a manner resembling strongly the lines of force of a magnetized sphere. Now it might be inferred from these phenomena that the Sun, like the Earth, is also enveloped by a magnetic field, and that the solar corona may be a phenomenon precisely analogous to our polar lights.

In fact, recent observations made under the direction of George E. Hale, Director of the Solar Observatory of the Carnegie Institution of Washington, definitely proved that the Sun is, indeed, a magnet, or at least acts like one. Hale also found that the polarity of the magnetic field of the Sun is the same as that of the Earth's magnetic field. That is to say, the Sun's north magnetic pole is near the Sun's true north pole, just as the Earth's north magnetic pole is in the region of the Earth's true north pole.

If the Sun possesses a magnetic field in spite of its high temperature, about 12,000° F., at which no magnetism as exhibited by permanent magnets could exist, what agency is essential for the production of a magnetic field? The question has been raised as to whether every large rotating mass may not be a magnet.[1] If so, picture to yourselves orbs innumerable spinning through space, "clothed, as it were, in gossamer garments woven of lines of magnetic force," pulsating, vibrating, ever interacting and responding to each other's external influences.

Our magnetic observations are registering daily by a photographic process mysterious messages—a kind of handwriting on the wall, as it were, which perhaps some day we may be able to decipher. "On that (photographic) paper," as Clerk Maxwell well said, "the never-resting heart of the Earth traces, in telegraphic symbols, the record of its pulsations, and also the slow but mighty workings of the changes which warn us not to suppose that the inner history of our planet is ended."

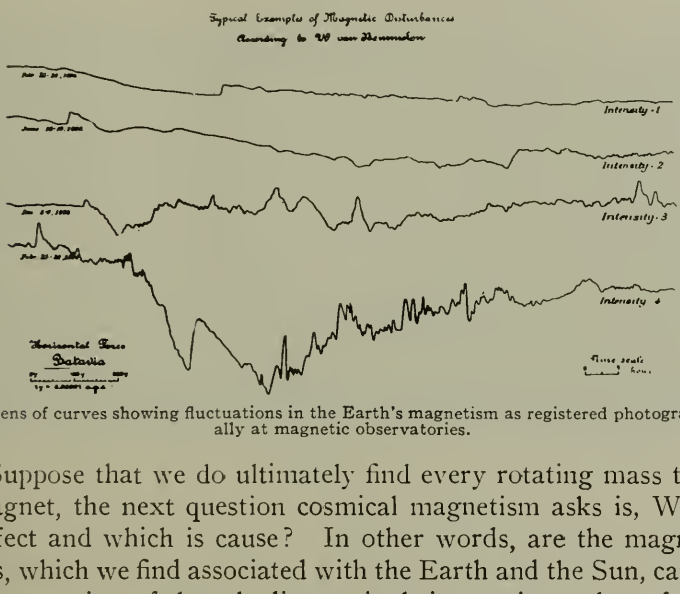
Listen to the receiver of a wireless station. Instead of hear-

[1] Among the various ways by which a magnetic field could be produced during rotation of a body is the following: Electricity in motion is equivalent to an electric current, which in turn is accompanied by a magnetic field. If, then, the Earth is electrically charged, effects will arise, during its rotation, similar to those of a magnetic field. We know electricity to be an essential constituent of all matter. Suppose that while the total positive charge within the Earth is equal to the total negative charge, the volume or sphere within which it is contained is slightly less than that assumed to contain the negative charge. In other words, suppose, because of some action, the volume density of the positive charge is a trifle larger than that of the negative charge. Then during the Earth's rotation magnetic effects will ensue similar to those actually observed. If the radius of the sphere assumed to contain the total negative charge exceeds the radius of the sphere containing the positive charge by 0.2×10^{-9} cm., or 0.02 of the radius of an ordinary molecule, or one forty-millionth of the thickness of ordinary writing paper, a magnetic field of the required strength will be produced during the Earth's rotation.

ing distinct, sharp messages, you are confused by a continual crack, crack, crack, resembling distant musketry. You are told that these extra and ever-occurring signals are the so-called " electric strays "—God's voice, as Professor Pupin recently said.

In the same way the picture (Fig. 10), which you now see of these magnetic curves, may contain the printed record of mighty cosmic events, the full import of which is at present a sealed book to us. Thus through the Earth's " electric pulse," and through its " magnetic pulse," strange things come to our knowledge. A truly prophetic vision must have been that of Orpheus, who declared, " With the lodestone, you can hear the voices of the gods, and learn the mysterious things of heaven."

FIG. 10.



Specimens of curves showing fluctuations in the Earth's magnetism as registered photographically at magnetic observatories.

Suppose that we do ultimately find every rotating mass to be a magnet, the next question cosmical magnetism asks is, Which is effect and which is cause? In other words, are the magnetic fields, which we find associated with the Earth and the Sun, caused by the rotation of these bodies, or is their rotation to be referred in some manner to preëxisting magnetic fields? Is it a mere coincidence that the direction of rotation of nearly all the planets and the direction of revolution around the Sun of all of them are the same as the direction of the Sun's rotation?

It is an interesting fact that Gilbert advanced his theory that the " Earth is a great magnet " largely to account thus for the Earth's rotation. To him the Earth was but a great, round lode-

stone. It had poles and an equator, just as the small magnetized globe, "earthkin or terrella," as it was called, with which he carried out his experiments, had its magnetic poles and its magnetic equator. Just as the terrella behaved with reference to the Earth, so did the latter with regard to universal space, and thus remained "constant in a fixed direction in the universe." Furthermore, the Earth turned on its axis just as the terrella did on its axis when floated in a bowl of water and brought under the influence of the Earth's magnetic force. He thought that the Earth's magnetic poles were coincident with its poles of rotation, and so it was natural, perhaps, that he should speculate "on the magnetick diurnal revolution of the Earth's globe," and ascribe it to some action in space.

It is a striking circumstance that the most noted astronomers to-day are seeking help from the student of magnetism in the solution of some of their problems respecting certain outstanding irregularities in celestial motions which cannot be explained merely by gravitational forces. They are even now postulating cosmical magnetic effects, in addition to those resulting from gravitation. Indeed, it is the ever-increasing belief that gravitation and magnetism are closely allied.

Here it will be of interest to quote Benjamin Franklin, who expressed himself thus:

"Has the question, How came the Earth by its magnetism? ever been considered? Is it likely that *iron ore* immediately existed when this globe was first formed, or may it not rather be supposed a gradual production of time? If the Earth is at present magnetical in virtue of the masses of iron ore contained in it, might not some ages pass before it had magnetic polarity? Since iron ore may exist without that polarity, and by being placed in certain circumstances may obtain it from an external cause, is it not possible that the Earth received its magnetism from some such cause? In short, may not a magnetic power exist throughout our system, perhaps through all systems, so that if men could make a voyage in the starry regions, a compass might be of use? And may not such universal magnetism, with its uniform direction, be serviceable in keeping the diurnal revolution of a planet more steady to the same axis?"

We thus see that the problems of the Earth's magnetism, or the answer to our question, "What is a magnet?" lead to the

very outer boundaries of human knowledge. When asked to what end we are studying and mapping out the magnetic state of our planet, we instinctively recall that well-known query, "What is the good of a new-born babe?" Can any one foretell the result of investigations the prime object of which is to learn how Nature carries out her experiments on a scale of magnitude far beyond the reach of any laboratory experiment that Man can devise?

FIG. 11.

The laboratory and headquarters of the Department of Terrestrial Magnetism at Washington, D. C.

CONCLUSION.

Says Schuster: "Atmospheric electricity and terrestrial magnetism, treated too long as isolated phenomena, may give us hints on hitherto unknown properties of matter."

Great problems then await solution. It is hoped that some of them will be solved in this Laboratory—the home of the Department of Terrestrial Magnetism (see Fig. 11).

But the hour has struck, I have "run my compass," and must dispense with further argument and illustration. I have attempted to show throughout the lecture that an inseparable bond unites the search for the beautiful with the achievement of the useful.

I cannot better sum up the common aims of science and humanity, so far as they may be exemplified by the subject of this lecture, than to recite Charles R. Clarke's beautiful lines on the compass:

Ho, burnish well, ye cunning hands!
  A palace home for me,
For I would ride in regal state
  Across the briny sea.
Bring ivory from the Indian main
  To pave my mystic floor,
And make my dome of crystal sheen,
  My walls of shining ore.

Now mount the wave, ye fearful ones,
  Though raging storms assail,
My sparry lance o'ercometh all—
  My strength will never fail.
The storm fiend wraps his murky clouds
  Around your trembling sight,
And I can pierce that gloomy veil,
  And soar beyond the night.

The lone enchantress of the deep,
  I rule its boist'rous realm;
Watch ye my lithe and quiv'ring wand
  To guide your straining helm.
Aye, bend your anxious gaze on me;
  The polar star is dim,
And driven darkness is awake
  With ocean's awful hymn!

For I commune with spirit forms,
  Within my wizard cell,
And mantling midnight melts before
  The magic of my spell.
By many long, enduring links
  I clasp the northern star—
And on the wiry-shadowed chain
  I visit her afar.

And sapient eyes have watched me long,
  And science has grown gray,
And still ye dream not how nor why
  I keep my wondrous way.
Ye know me as you know the storm
  That heaps your heaving path,
Ye love me, though, since mine is not
  The mystery of wrath!

THE TRANSMISSIBILITY OF DISEASES, AND THE PUBLIC HEALTH.*

BY

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AMONG the writings and in the discussions upon vital statistics, one constantly encounters the expression "Deaths from preventable diseases." The uninitiated may properly inquire what are the "preventable" diseases, and what is the justification for so designating them.

If one examine the mortality returns for any or all of our larger centres of population, one notices that they may be classified, roughly speaking, into two approximately equal groups; the one comprising those from non-preventable causes, the other those from causes more or less controllable. For instance, in the annual report of the Bureau of Health of this city for the year 1914 one finds the deaths in the former group bear the relation to those in the latter group, roughly, that 10 does to 8. In the first group are comprised deaths from those manifold degenerations arising within the living body; due in some instances to disturbances of physiological functions peculiar to the individual; in others to constitutional or tissue defects referable to hereditary taints; in others to the destructive influences of vicious habits in eating, drinking, or exercise; in others to the wearing out of the human machinery coincident with old age, and in others to the inability of a new and imperfect organization to meet the strain incidental to the beginning of normal life, as in infancy.

Throughout this group we find that disease and death result from causes operating upon the individual and having but little, if any, influence upon the health of the community at large. While this class is usually denominated the "non-preventable" diseases, theoretically, through attention to breeding, education, and personal habits, the influences of their underlying causes should be lessened and their effects postponed.

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* Presented at the stated meeting of the Institute held Wednesday, December 15, 1915.

In the second group, however, we encounter a very great variety of diseases that may be regarded as dependent upon environmental influences; that is to say, their occurrence depends upon the action upon the tissues of agents that in one way or another are associated with the conditions under which we live, or to which we may have been exposed.

As we look further into this second group, utilizing modern knowledge and methods, we discover that in all cases the diseases from which the deaths resulted are the outcome of the invasion of the body by various kinds of living parasites. In other words, they are infective diseases. We find, furthermore, that from all such diseases the causative parasites escape in a living state in one way or another, retaining their power to reproduce the disease in new hosts to which they may gain access—in other words, we find the infective diseases to be transmissible.

As we become more and more familiar with the manifold modes of transmission and with the means adequate to interrupt it, the belief is becoming general that all diseases known to be transmissible are, *ipso facto,* preventable.

It is important to note that certain diseases now known to be infective and transmissible were formerly regarded as not so, and it may be profitable to pass in brief review the growth of knowledge that has brought about the reversion of opinion and made a proper classification possible.

For instance: One need not revert to a very remote period when the word "miasmatic" was used to designate a group of maladies which were supposed to originate from the breathing of air arising from marshy lands. Such diseases were not believed to have any relationship to other cases of the same disease, but all were supposed to develop from the deleterious action of the mysterious miasm. Malarial fevers and yellow fever may be cited as the most conspicuous illustrations of that conception. It is still a fact that both diseases are usually observed in the neighborhood of marsh lands and low-lying littorals, but our new knowledge has placed in our hands the correct interpretation of the relationship. It is not a gaseous emanation, as was formerly supposed, that excites these diseases, and neither the air of marshes, even most dangerous, nor the water of such marshes has, *per se,* the least influence in exciting the fevers. Three important facts explain the whole matter: *First.*—These fevers are due to the in-

vasion of the body by microscopic parasites having the power to destroy the cells of the blood. In malarial fever this is no longer in question; in yellow fever, while no parasite has as yet been seen, still, all trustworthy circumstantial evidence indicates its presence in the diseased body. *Second.*—That the parasite present in the blood of the diseased person can invade and infect the body of another person, but only through the agency of an intermediary host—a mosquito. *Third.*—That the mosquito is an aquatic animal for a part of its life. At once the miasm matter receives full and adequate interpretation. This information is of such obvious, fundamental importance in the prevention of marsh fevers as to require no further discussion. It is of importance to note, however, though we are still in complete ignorance of the specific parasite of yellow fever, we know that the disease is spread and how it is spread, and by destroying the agents concerned in its dissemination it is abundantly demonstrated that the disease may practically be eliminated.

Up to the late eighties there were still teachers of great importance who did not believe that the germ of typhoid fever was capable of producing infection if transferred directly from the sick to the well.

Von Pettenkofer—sometimes known as the father of modern hygiene—died with that belief firmly fixed in his mind. In his opinion, infective parasites—especially such as the germs of typhoid fever and of Asiatic cholera—required to be influenced by the soil before they became dangerous. The rise and fall of the soil water developed a condition, designated by him as "hypothetical x," to which the germs had to be exposed before they were capable of reinfecting. A few thought that the late summer and early autumnal occurrence of this disease was in one way or another referable to the death and decay of vegetation. Our modern conceptions are altogether different: we know that the intestinal infections—typhoid fever, Asiatic cholera, and dysentery—are due to the actions of living germs that may be, and very frequently are, transmitted in a variety of ways, either directly or indirectly, from the sick to the well, and that in most such cases new infections occur. We know that such germs, if allowed to gain access to the soil, remain alive for varying lengths of time and retain all their original infectivity. We know that from such polluted soil drinking water may and does become polluted, and is

then a potent agent in disseminating the diseases. We know that there are no mysterious modifications of the characters of these parasites in operation in the soil. We know that foodstuffs, such as milk, vegetables grown on land fertilized with infected night-soil, shell-fish freshened in polluted waters, may from time to time be the means of spreading the disease. We know that convalescents from all the diseases of this group may serve to originate serious outbreaks, and an abundance of evidence points to the frequent direct infection of those in attendance upon the sick through the simple process of personal contact.

In other words, we are dealing here with three serious infections of the intestinal tract. With every discharge from the bowels, living germs, capable of infecting others, are evacuated in enormous numbers. These diseases are known to be transmissible, and are so obviously preventable by appropriate methods that the widespread existence of one of them—typhoid fever—constitutes a serious commentary upon our intelligence and often upon our integrity.

For about a hundred years we have been aware of the existence of a specific disease commonly seen in the throat: to-day we know it as diphtheria—formerly it was known as "putrid sore throat," "angina suffocative," etc. For most of the time it was hopelessly confused with croup and with the sore throat common to scarlet fever. Since the early eighties, when its exciting cause was discovered, our knowledge upon it has progressed with such leaps and bounds that probably there is no disease over which we could have such complete control, were it possible to secure the necessary coöperation. All mystery concerning its origin and spread is cleared away: we know it results from the activities of a definite, easily recognizable parasite; that the parasite remains on the diseased tissues during the course of the disease and in a living infective condition for varying lengths of time after all constitutional signs of the disease have disappeared; that the parasite may be passed in manifold ways from the sick or the convalescent to those coming in contact, but, as will be shown presently, with the discovery of the parasite and an acquaintance with its life processes, means have been discovered by which not only the sick may be cured, but the well fully protected from the invasion of the germ.

Probably no more important medical discovery was ever made

than that tuberculosis is an infective disease due to a living parasite that may be passed from the sick to the well. Doubtless there are in this audience persons who recall the time, not very remote, when heredity was regarded as the great and all-important factor in the spread of consumption. What a handicap! Can you conceive of greater discouragement than to start in life with the firm conviction that because a parent, a brother, or sister, or another near blood relative had died of consumption, the disease was "in the family," and that you yourself were doomed to fall a victim, often at the time when one should be in the very prime of life? Yet not many years ago, hundreds—yes, thousands—attempted life with that thought constantly before them. What are our views to-day? We still know that tuberculosis may occur more frequently in some families than in others, but we believe its existence due to causes other than heredity, and perhaps of far more significance in perpetuating the disease. The main point is, however, that while a constitutional or tissue condition of relatively low resistance may be transmitted by heredity, strictly speaking, the actual disease is not so passed along, and it is important to note that such lowly resisting constitutions may often be very much strengthened by the practice of ordinary methods of personal hygiene. As in the case of all infections, the germ of tuberculosis may leave the body in a living, infective condition and may produce the disease wherever it finds suitable soil; *i.e.*, tissue conditions suitable for its growth. Studies upon the various manifestations of tuberculosis have acquainted us with the manifold ways by which the parasite escapes from the diseased body and the portals through which it may gain access to the well. All this is without mystery—all this is information of such a character that it can readily be presented to the lay mind in a comprehensible way; and, if there is one factor more than another that is operating toward the lessening of the frequency of this disease, it is the continued dissemination of knowledge upon it that has been going on so vigorously during the past few years.

Another striking illustration of fact supplanting fiction is in the matter of lockjaw—tetanus, as it is properly called. We used to believe that the incidence of the disease was influenced by certain conditions of the weather and by certain geologic conditions. Then came the rusty nail as a potent agent for causation, then the toy pistol and the other explosive agents, through which youth

is encouraged to express its patriotism. What are the facts? The facts are that tetanus, or lockjaw, is a bacterial infection; that the bacteria concerned are irregularly distributed in the soil; that they are often found within the intestinal canal of herbivora, and that, as they possess the power of entering a dormant or resistant stage, they may lie in the soil for a long time without losing the property of causing fatal infections when they gain access to wounds. It is the presence in the soil of this organism that explains the occasional action of the rusty nail in causing tetanus; it is its presence in the soil that explains the tetanus sometimes resulting among children with dirty hands from the toy pistol and other gunshot wounds to which dirt gains access; it is its wide distribution that serves to explain some, at least, of the cases of tetanus that develop after vaccination among persons of uncleanly habits. In other words, dirty wounds may always be looked upon with suspicion. It is this knowledge that has led recently to the uniform early use of tetanus antitoxin among soldiers wounded during the present war, with the result that tetanus following upon gunshot wounds has practically ceased.

In medical literature accounts are occasionally given of more or less widespread outbreaks of pneumonia. We know this disease to be caused by a specific parasite that leaves the body in a living state in enormous numbers during the course of the disease. It is not improbable that epidemiological factors not yet clear to us may be effective in favoring the spread of this disease from one person to another.

Cerebrospinal fever, infantile palsy, and influenza, all of which were formerly ascribed to the most diverse and sometimes mysterious influences, are now known to be infections, pure and simple; and that the parasites causing them pass, in different ways, from the diseased and enter the healthy body, thus reproducing the maladies in the bodies so invaded.

Common inflammations, boils, abscesses, child-bed fever, erysipelas, wound infections, and the like have all been found to be infective in nature, and easily prevented by the adoption of simple, common-sense precautions, cleanliness being the most important.

With regard to another group of preventable diseases—measles, scarlet-fever, chicken-pox, whooping cough, and small-pox—our knowledge is far from satisfactory. We do not know definitely what it is that causes them. We know that all are trans-

missible; that at certain stages they are more readily transmitted than at others; that they seem to be contagious in the strict sense of the word; but, as said, knowledge is incomplete.

Measles we know to be most infective during the pre-eruptive stage; therefore, probably its parasite is contained in the secretions from the eyes, nose, and mouth, and is given off during the prodromal stage. But no parasite has been recognized thus far.

Scarlet-fever we believe to be more often transmitted by the secretions from the nose, mouth, and ears than in other ways, though the scales from the skin are also believed to be infective. As in the case of measles, no parasite has been identified as the cause of scarlet-fever.

The same may be said for the other members of this group. Until we possess more information, measures to prevent the spread of these diseases will of necessity be only in part effective.

In the evolution of knowledge upon the transmissible diseases, light was first thrown upon the problems by the utilization of trustworthy bacteriological methods of investigation. Many of the commonest infective diseases were quickly shown to originate with the invasion of the body by bacterial species that were easily identified. This was particularly the case with tuberculosis, typhoid fever, erysipelas and wound infections, diphtheria, cholera, and a large group of infections of domestic animals that are transmissible to man. But the persistent application of such methods to the analysis of other diseases, obviously of an infective nature, did not supply such satisfactory results. In so far as the proved bacterial infections are concerned, it was possible not only to isolate the causative parasite but to cultivate it artificially, and, finally, to reproduce the disease in animals with the remote descendants of the original parasites obtained from the diseased body. For many obviously infective diseases this was not possible. Parasites could be detected by microscopic examination of the tissues and fluids of the diseased body, but no means were available for their cultivation, or their study under artificial environment, and it was only occasionally possible to reproduce the diseases by direct inoculation.

These obstacles were, in part, finally overcome by the discovery that such diseases as malarial fever, yellow fever, relapsing fever, and certain other exotic maladies are due in some cases *positively* to protozoa (*i.e.*, to animal parasites—not bacteria), and

in others *probably* to parasites of the same general nature. The failure to reproduce the disease by transferring the living parasite from the fluids and tissues of the diseased person to the bodies of the susceptible animals suggested the possibility of an intermediary host being essential to the transference.

Sir Ronald Ross made the important demonstration that certain birds in particular parts of the world were infected by an hæmatozoön strikingly like that seen in man during the course of malarial fever, and that such parasites become infective for other birds only after a sojourn in the body of a mosquito, where they undergo phases of development essential to ultimate transference and infectivity. This demonstration, when applied to the study of malarial fever in man, revealed the fact that the disease is transmitted in this, and only in this, way. Similar observations on yellow fever have brought out the same fact. These results at once attracted attention to the possible rôle of insects in the general dissemination of disease. The outcome of investigations in this field has been of the utmost importance. We now know that insects transmit disease in at least two ways: one, by themselves being appropriate hosts for the parasite concerned; the other by acting mechanically as vectors—*i.e.*, as simple carriers of infective particles from infected persons, animals, or matters to other persons, either directly or indirectly, by way of the food or drink.

In those bacterial infections where the exciting bacteria leave the body with the discharges—as is the case in typhoid fever, Asiatic cholera, and dysentery—numerous insects which frequent the places of deposit may, by becoming soiled with the infective matters, carry such infection into the household and deposit it upon a variety of foodstuffs that serve to support the life and multiplication of the parasite.

Other bacterial infections that are more or less confined within the body, as blood-poisoning, bubonic plague, erysipelas, splenic fever, or anthrax, may be spread by biting and blood-sucking insects without the insect either suffering from infection or being, properly speaking, an intermediary host for the development of the parasite.

As a result of this knowledge, we have come to look upon all insects as menaces to the public health, and this is especially true of those insects that suck the blood of man.

It is now established beyond peradventure that various species of mosquito are concerned in disseminating malarial fever, yellow fever, and elephantiasis; that certain flies are concerned in the perpetuation of sleeping-sickness and the trypanosomiases of animals; that ticks and bed-bugs are the intermediary hosts for the parasites of relapsing fever; that the body louse is the means of disseminating typhus fever; that the rat flea is the active spreader of bubonic plague, and that the common house-fly is one of the frequent means by which all intestinal infections are spread.

Not many years ago it was the common opinion that a patient who had suffered from an infective disease was free from danger to others when he had become well enough to leave his bed and get about. Developments of recent times justify the opinion that this is not always the case.

In so far as several important infections are concerned, we know that the convalescent may sometimes be a menace to others for long into the period of convalescence, even into complete recovery of health and usefulness.

These rather rare cases constitute one phase of the "carrier problem," a problem new to the practitioner of preventive medicine and one beset with many embarrassments for those responsible for safeguarding the public health. Not less awkward is the fact that now and then persons are encountered who may not themselves have suffered from an infection to which they may have been exposed, but who have in one way or another received the infective germ upon or in their mucous surfaces, and thus unconsciously they serve for various lengths of time as sources of supply for such parasites to others.

Up to the present we have no practical means of satisfactorily eliminating this danger. The detection alone of carriers—be they among convalescents or those in full vigor—is a task of such magnitude as to make its completion a matter of grave doubt. We can only recognize their existence and warn against too intimate contact with those recovering from acute infections—especially from the intestinal infections, from diphtheria, scarlet-fever, cerebrospinal meningitis, pneumonia, and infantile paralysis.

Probably one of the oldest medical riddles, and certainly one of the most interesting, is that in which we are called upon to explain why a person who has recovered from a specific infective

disease is not likely to suffer again from the same disease. It is not astonishing that the endeavor to solve this puzzle has engaged the attention of the most competent philosophers and investigators of all times. It was not, however, until comparatively recently that anything approaching a satisfactory solution has been forthcoming, and even now our information leaves much to be desired.

This is scarcely the place or the time to lay before you the bewildering mass of biological, physical, and chemical details that underlies the opinions held at present upon this subject. It will suffice to say, vague as it may sound, that in the course of a non-fatal attack of an infectious disease the tissues of the body undergo a reaction toward the causative agent of that disease that enables them to protect themselves against a subsequent invasion of the same parasite. In some instances—as in the case of diphtheria and tetanus—this tissue reaction manifests itself by the appearance, within the body, of specific antidotes which, by neutralizing the poisons manufactured by the parasites, counteract the destructive effects of such poisons on the vital organs. As the free poisons elaborated by bacteria are known as "toxins," and as diphtheria and tetanus are typical intoxications, the antidotes manufactured by the tissues of those who recover from such diseases are known as "antitoxins." It is of fundamental importance to note that not only do these antitoxins appear in the body of the person who has recovered, but that by particular methods of procedure their production may be artificially induced in lower animals, and may be carried to a point at which they are present in the blood of the animals in amounts far greater than that ever seen in man. But this is not all. If such animals be now bled, it is found that the antidote may be obtained with the blood, in an unaltered state, so that its neutralizing or antidotal value is preserved and may be demonstrated by so simple a procedure as bringing it and its homologous poison together in a test-tube. Furthermore, if it be injected into the body of a person suffering from infection or intoxication by the homologous parasite or poison, it exhibits again its neutralizing properties; *i.e.*, it cures the disease. Of equal importance is the fact that its injection into the tissues of well persons serves to shield against infection by the corresponding germ, or against intoxication by the specific poison of that germ. Both the curative and preventive values of diphtheria

and tetanus antitoxins are so well known as to require no further debate at this time. They constitute our most important agents in combating these diseases.

In another, larger, group of infections we find free poisons playing much smaller rôles than in the case of diphtheria and tetanus. In this group the protein materials of which the parasites themselves are composed are poisonous, but these probably can not, or do not, exhibit toxic activity until the bacteria are disintegrated within the tissues. Antitoxins, strictly speaking, are of no avail in antagonizing such infections, and they are not found in the blood of those recovering from such infections. In the course of normal, non-fatal infections, as well as by special artificial means for stimulating tissue reactions, there seem to be elaborated by the cells of the body antibodies capable of rendering inert such intracellular poisons as are concerned in this type of infection. Our knowledge here is far less complete and satisfactory than that covering the true toxic infections and their antidotes. Nevertheless, in the course of investigations bearing upon this group we encounter certain cells of the body which appear to possess a scavenging function; *i.e.*, they are wandering cells, having the power to travel about the body, pick up, and digest within themselves such objects as are digestible, among such being invading bacteria. It is of importance to note that, in the main, the efforts used to stimulate tissue reactions that may protect from infections of the type under consideration stimulate, at the same time, in varying degrees, the activities of these scavenging cells and render them more energetic in picking up and destroying invaders.

It is this idea that underlies the very modern practice of vaccinating against bacterial infections, by the injection, into the body, of dead bacteria of the same kind as those causing the infection against which we are operating. The enormous reduction in both morbidity and mortality from typhoid fever that has resulted from vaccination with dead typhoid germs is a striking illustration of what may be accomplished, even though it is not possible to fully explain the mechanism of the reaction. Similarly, in the case of Asiatic cholera, much sickness and many deaths have been prevented by analogous procedure. To what extent the method is generally applicable can not now be determined, but it seems logical at bottom, and with further growth of knowledge may

prove, with appropriate modifications, to be a most valuable adjunct to our armament against certain types of infective maladies.

With the foregoing facts well established, it is clear that logical preventive measures are possible.

As the methods of disposal of human waste had always been of a nature to certainly pollute the soil and waters—and as our knowledge had demonstrated that such waste matters usually contained the living germs of various infective diseases, which germs retain their life and infectivity outside the body for varying lengths of time—it is not surprising that attention to this abuse was one of the first and most important steps in the direction of modern hygiene. The opinion had prevailed that, even though grossly and continuously polluted, both soil and water possessed the power, by natural processes, of quickly rendering inert such pollution. A number of important commissions expressed the belief that this, while true in a way, can not be relied upon as a safeguard against the dissemination of disease. In consequence efforts were made to prevent soil pollution by substituting sewerage systems for cesspools and privy vaults, and to adopt artificial methods for the purification of such drinking water supplies as are of necessity polluted or likely to become so. The outcome of these efforts has been so uniformly concordant in lessening infective diseases, especially those of the intestinal canal, as to justify our placing them in the first rank of public sanitary improvements.

In the meantime many outbreaks of transmissible diseases had been suspected of originating with certain food—milk in particular. It was now possible, by the application of modern methods of investigation, to decide this point. The studies upon milk, of milk-producing animals, and of other domestic animals used as food, have shown that many infections of animals are readily transmissible to man in a variety of ways. This has led to a sanitary control of food-producing animals that is quite as rigid and just as important, as a safeguard, as is that being applied to human beings.

Overcrowding and filth had long been regarded as potent for the dissemination and perpetuation of transmissible diseases. With the development of information upon the essential nature of infection and the ways in which infection is transmitted it is possible to formulate regulations for the elimination of these evils.

Not less important are the results of investigations upon the individual. The old term " vital resistance to disease " has now a definite meaning. It is known that we make our *début* in life endowed by nature with a more or less measurable degree of resistance to the invasion of hurtful parasites. Later investigations have shown that such resistance may be depressed or accentuated according to the way in which we live, and, furthermore, in so far as specific infective diseases are concerned, it may, by artificial means, be increased very greatly over the amount with which nature endows us.

A rational life—meaning by that, fresh air, personal cleanliness, nutritious food, exercise and rest in moderation, and the avoidance of those abuses known to interfere with our well-being—always operates in maintaining our natural resistance to the highest point of efficiency. In so far, however, as specific infections are concerned, these means are never sufficient to guarantee protection. One of the most important of the modern problems in preventive medicine is to discover harmless means whereby such protection may be given the individual.

As stated above, the individual who has recovered from an infectious disease is not likely to experience a second attack—we believe that condition to be due to certain cellular reactions that went on in the body during the course of the primary attack. Experiment has shown that these protective reactions may be induced in animals by artificial means that do no harm whatever to the animal, and in numerous instances in which the method has been tested on man it is found that he, too, may be protected. The cellular reaction results from the stimulating influence of the poisons of the parasite upon those tissue elements for which they have specific affinity. When such stimuli are injected into the animal in such small amounts as never to endanger life, the reaction still occurs and its degree may be accurately estimated. Applying this to man, we find that by vaccination, in a variety of ways, the individual resistance to several dangerous diseases may be so increased that the individual becomes immune. This result we see from vaccination against small-pox—where living virus is employed. We see it in vaccination against typhoid fever, Asiatic cholera, and plague—where dead vaccines are used. In protection from diphtheria by the use of antitoxin we observe a different phenomenon—here the human being is simply the passive

recipient of an antidote that has been manufactured in the body of another animal, in which specific cellular reactions have been induced. We are scarcely more than over the threshold of this important field of activity, yet the results thus far obtained justify the hope and belief that future developments will prove of inestimable service to the cause of preventive medicine.

What can be accomplished in the future is well indicated by that which has been accomplished in the past. Through attention to diet, and ordinary conditions of cleanliness, scurvy, typhus fever, and relapsing fever have been caused practically to disappear. It now seems likely that beriberi and pellagra will be eliminated by dietary measures.

By the adoption of approved, common-sense sanitary precautions, intestinal infections—as indicated by typhoid fever—may be enormously reduced. By faithfully practising that which we know concerning the isolation and care of the acute contagious diseases, their spread may be markedly lessened.

Diphtheria has for most people lost its terrors, and its excessive ravages of times gone by are now only of historic interest.

In malarial and yellow-fever districts safeguards against the mosquito and measures toward its destruction have given almost complete protection.

The common house-fly is not only a nuisance, æsthetically speaking, but is proved to be a serious menace to health under certain circumstances; and there are good grounds for the opinion that any and all insects commensal with man may be, and often are, the active agents in the transmission of disease.

I have touched only upon what I regard as the essentials in this important problem. I have taken pains to rob the subject of all obscure technicalities; to indicate that real knowledge is now available, and to insist that we should demand its application to the solution of the problem in which we are all so deeply interested.

Many fundamental phases of public hygiene are of such simplicity as to lend themselves to teaching in our schools, and it is hoped that some time we may see such teaching in operation.

For the further improvement of conditions it is not necessary for us to wait until more discoveries are made—even though this is desirable in certain directions—nor for new legislation to be enacted, for by the faithful utilization of that which is available, enormous benefits may arise, and that, too, without the discovery of a single new fact or the passage of a single new law.

RECENT PROGRESS IN FLOTATION.*

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I. INTRODUCTION.

One of the most marked and revolutionary advances of recent years in the art of concentrating ores is the advent and application of the flotation process. Although the basic and essential principles of flotation had been disclosed by the early work of Haynes, Everson, and the Elmore brothers, it is only within the last decade or so that the process has been a commercial success. Historical considerations point out the fact that the installation of the Delprat process, in 1903, at the Broken Hill Proprietary mine in Australia, was probably the first important commercial application of any flotation process; some other installations were also made at or about the same time. Flotation as practised to-day is the result of the diligent labor of many men, and the present state of development cannot be ascribed to any one individual. In its early stages the flotation process of concentration was decidedly uncertain of success because of certain inherent difficulties which were to be overcome. At present every mill owner in the country is considering its applications. The froth flotation process is markedly efficacious in extracting the mineral sulfides from slimes, and, in the main, is more or less restricted to the treatment of extremely fine material.

In a general way, there are three divisions into which the flotation processes may be separated; namely, (1) film flotation, (2) bulk-oil flotation, and (3) froth flotation. Further, these three classes blend into one another gradually, according to the patents secured for the different processes. Technical distinctions are based on such points as these, viz., acid, neutral, or alkaline pulp solutions; mill temperature or hot solutions; various secondary apparatus employed for the introduction of air or the production of gas bubbles; amounts of oil; and other minor differences almost *ad infinitum*. The more important processes which

* Communicated by the Author.

have so far survived elimination by litigation or other means include the following: Minerals Separation process; Potter-Delprat process; De Bavay process; Callow pneumatic process; Hyde process; Janney process, and the Macquisten tube process; and, further, the preferential processes—Murex, Lyster, and Horwood. These processes have been described at length in the patent literature, in the scientific press, and elsewhere, and further comment would make this writing unnecessarily cumbersome.

Strictly speaking, the subject of flotation naturally falls into two divisions, to wit, legal disputes and technology. Litigation has undoubtedly been the most active, as well as destructive, movement in the field, for the development of the process has been constantly attended with an unwholesome amount of legal differences among the contending interests. Probably there was never a technical achievement so hotly contested in the courts as this one. All these involved disputes have so distinctly retarded progression in this process that, charitably speaking, flotation is to-day in a chaotic state.

Regarding present operations, although there are so many flotation plants at work, there is a decided dearth of available data. In short, actual results have not found their way into the literature devoted to mining and allied subjects, presumably on account of the veil of mystery which is supposed to, and actually does, hang over the process. Practice varies with the locality, and, as a whole, the methods are in no sense standardized. Development at the present time is being retarded on account of certain cases pending in the courts, which involve the Minerals Separation, Ltd., and others. For, with these cases still to be adjudicated, many operators seem to hold that any attempt at development and standardization would be folly, which would incur a certain waste of time and money, should the decision be rendered in what is considered the unfavorable way.

II. PROGRESS IN VARIOUS LOCALITIES.

Australia.

To all intents and purposes Australia is in the van in flotation at present, and has been since the advent of the process. The first important flotation installation was that of the Delprat process, as mentioned in the foregoing; this mill operated successfully from its inception and has continued to do so. The joint Potter-Delprat

process was also applied to the treatment of ore at the Broken Hill Proprietary Block 14 Company's mine in 1903, but ceased operations in 1905; whether this particular plant ever recommenced operations is not known to me. These installations, however, mark the beginning of the remarkable growth in the zinc industry of Australia, which country now produces one-fifth of the world's supply of spelter. The Potter-Delprat process is peculiarly adapted to Broken Hill ores, and this fact is the main reason for its marked success; on other ores it may not be as efficient as some of the other processes.

The Minerals Separation process, licensed by the Minerals Separation, Ltd., and the Minerals Separation American Syndicate, Ltd., was first employed about 1904–05 by the so-called Sulfide Corporation in Australia. In brief, the process then was an adaptation of the Cattermole patent, the principle of operation being the coagulation and sinking of the mineral sulfides with a large amount of oil. The original idea of Cattermole was abandoned in 1905 and true froth flotation adopted. The Minerals Separation process was practised in 1907 at the Central mine at Broken Hill, and has operated successfully to date, producing zinc concentrates. At the same time the Minerals Separation, Ltd., by right of purchase secured a large tailing dump from the Sulfide Corporation; the Minerals Separation process was applied to the concentration of the material, and the mill was an immediate success, producing good concentrates. During this time flotation was subjected to rigid experimentation throughout the Broken Hill district, and the practicability of the process was satisfactorily demonstrated. Minor improvements made from time to time have brought it to its present state of perfection.

It is a noteworthy fact that the introduction of flotation at Broken Hill resulted in the total scrapping of the electric separating machines, all being renounced because the newer process effected an extraction of from ten to twenty per cent. more zinc. Previous to the introduction of the Horwood process, it had been impossible to successfully separate the lead and the zinc in the flotation concentrates into marketable products. Owing to the slimy character of the concentrates delivered by the flotation units, the method of further treatment on tables was an imperfect one; this handling was practised, however, as none other so good was available.

The Zinc Corporation, Ltd.,[1] by reason of extensive experiments with the Horwood process, has definitely adopted it as a preferential method of separating the zinc and lead sulfides in the slime concentrates. Briefly, the Horwood process involves a partial sulfatizing roast of the material to be treated, which coats the lead sulfide particles with $PbSO_4$, while the other sulfides of the ore, zinc, iron, and copper are not so affected. The galena is thus " deadened," and the sphalerite may be floated in the ordinary manner in a Minerals Separation or other flotation machine. According to a report of the Zinc Corporation,[2] the Horwood process is a practical installation at its plant. Figures from the most recent annual statement show that the lead flotation plant treating tailings from other companies' mines and also ore from the Zinc Corporation South Block mine produced 26,567 tons of lead concentrate assaying 64.6 per cent. Pb, 6.45 per cent. Zn, and 9.2 ounces Ag from 141,667 tons of ore assaying 14.4 per cent. Pb, 9.3 per cent. Zn, and 2.6 ounces Ag. The zinc flotation plant for the same period treated 221,620 tons of tailings assaying 13.68 per cent. Zn, 5.93 per cent. Pb, and 6.42 ounces Ag, yielding 63,300 tons of zinc concentrates assaying 43.96 per cent. Zn, 13 per cent. Pb, and 13.91 ounces Ag. Of the original material treated in this latter plant, 169,180 tons were dump tailings and the remainder was from the lead plant mentioned above and the British and Junction mines. The Horwood process plant in the same time yielded 5822 tons of zinc concentrates assaying 48.1 per cent. Zn, 6.80 per cent. Pb, and 16.90 ounces Ag; and 2619 tons of lead concentrates assaying 35.55 per cent. Pb, 14.0 per cent. Zn, and 40.52 ounces Ag. The material treated in the process just mentioned included 6144 tons of zinc slime from the zinc plant and 3169 tons from the accumulated dumps for a return as indicated. The cost of operation of the Horwood plant was 30 cents per ton of ore.

A Minerals Separation plant was started in July of 1911 at the Kyloe Copper mine in New South Wales. The flotation yields a 22.65 per cent. copper concentrate from low-grade ore with an extraction of 86.36 per cent.

[1] *Mining and Engineering World*, Jan. 2, 1915, p. 13.

[2] *Mining and Scientific Press*, July 17, 1915, p. 91.

Experiments[3] made in 1913 at Mt. Morgan, Queensland, resulted first in the erection of a 300 to 400 ton-per-day experimental Minerals Separation unit. The ore contained about 2 per cent. Cu as chalcopyrite and $6 in gold per ton. Tests in the experimental unit were satisfactory, and the erection of a 1000-ton plant followed. The work on this cupriferous gold ore showed that all ore had to pass 60-mesh, or good extraction could not be had; and up to 120-mesh the extraction increased in proportion to the fineness of the grinding.

The Elmore Vacuum Oil process was tried by the Zinc Corporation at Broken Hill and later discarded in favor of the Minerals Separation process. The Elmore Vacuum process is not finding much application to-day; most of the installations are in Europe or the British Isles. The so-called De Bavay process was secured by the Minerals Separation, Ltd., in a merger of interests. The De Bavay process is preëminently fitted for the treatment of sands, the tailings or other products to be floated being first deslimed. It will effectively treat material through 30-mesh and not over 5 to 10 per cent. of slime, which is much coarser than the Minerals Separation process can successfully cope with. For fine material, *i.e.*, slimes, the latter is eminently suited, while the De Bavay process is not so efficient.

Work at the Whim Well in western Australia with the ingenious Murex process demonstrates that this preferential method has potentialities; and its future probably lies in the concentration of cupriferous carbonates or other oxidized ores. Another preferential process which was developed in Australia is the Lyster process, owned by the Minerals Separation, Ltd. This process was worked out in detail at Broken Hill, at the Zinc Corporation plant, and received favorable consideration from that company for some time previous to the present great war.

The importance of Australia to-day is due in great measure to flotation, for in less than a decade Australia has risen to the position of furnishing one-fifth of the world's supply of zinc. No mining camp in the world produces so much zinc as Broken Hill. The first shipment of zinc concentrate in 1903 from that place was 50 tons; in 1911, 470,000 tons of 47 per cent. grade zinc concentrate were produced by flotation methods.

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[3] *Mining and Scientific Press*, June 27, 1914, p. 1044.

Arizona.

Flotation has gone forward rapidly in Arizona in the last few years, and there is at present great activity in that state because of recent large installations. A noteworthy flotation plant [4] is that of the Inspiration Copper Company, near Miami, Ariz. At this place there are available some 100,000,000 tons of a 1.63 per cent. copper ore, the copper being mostly in the form of chalcopyrite and containing about 0.20 per cent. copper as silicate and carbonate. A large amount of experimental work was first performed previous to the erection of the present mammoth mill. The Minerals Separation process, Callow process, Towne-Flinn process, a process devised by D. Cole, of Morenci, Ariz., and a so-called Inspiration process were tried. The first Minerals Separation unit was ready for work in December of 1913, but commencement of operations was retarded on account of power failure; this plant was designed for a capacity of 600 tons per day. The Inspiration process was designed by the metallurgists in charge and was intended to embody the best features of the other machines without infringing on any of the patents except those of the Minerals Separation, Ltd. The Inspiration Company is licensed to operate under the patents of the latter. The present new mill [5] has a capacity of 7500 tons daily, and when the entire plant is in operation will have a capacity of some 14,000 to 15,000 tons. In addition, the experimental unit is still operating.

The introduction [6] of the flotation process, together with some minor changes in the mill of the Consolidated Arizona Smelting Company, resulted in an increased copper recovery of 20 per cent. The ore contains 2 per cent. of copper as chalcopyrite, with pyrite in a schistose and quartzitic gangue. The former mill system was necessarily complicated because of the nature of the ore; the chalcopyrite, being of a friable nature, caused heavy losses, but the pyrite was more easily concentrated, as it broke coarsely. Although the same ore, the one from the Blue Bell and De Soto mines, is being worked, the flotation process has ameliorated the heavy losses and is effective where concentration on tables was not. In September, 1915, flotation was responsible for a recovery

[4] *Mining and Scientific Press*, July 3, 1915, p. 7.

[5] *Mining and Engineering World*, Jan. 1, 1916, p. 1.

[6] *Metallurgical and Chemical Engineering*, Dec. 1, 1915, p. 897.

of 240,000 pounds of copper concentrates, about 70 per cent. of the total. This company was among those which first used the Minerals Separation process in the United States. An 11-cell unit with a capacity of 225 tons per day has been installed, and the flotation is consummated in non-acid solutions at mill temperature. The concentrates are not recleaned. The oil combination which was found most effective consists of about two parts of wood creosote to one part of a cheap stove oil (light burning oil). The cost of operation is about 27 cents per ton, of which the oil expense contributes 0.028 cent.

The Magma Copper Company [7] at Superior and the Duquesne Mining and Reduction Company at Duquesne have installed the Callow pneumatic flotation process. The invention of Callow [8] marks one of the most distinct advances ever made in flotation. This process calls for agitation with air in an acid, neutral, or alkaline solution, with oil as selective and frothing agent. At Superior the tailings from the finishing tables receive flotation treatment. There are flotation units in experimental operation at the Copper Queen Consolidated Mining Company's mill at Bisbee. Other flotation plants in Arizona include those of the Ray Consolidated Copper Company at Hayden and the plant at the Old Dominion mine. The flotation work of the Miami Copper Company at Miami has become involved in litigation with the Minerals Separation, Ltd.

Idaho.

Flotation has become an important metallurgical process in the Cœur d'Alenes and elsewhere in Idaho. The Callow pneumatic process was applied to the treatment of ores at the mill of the National Copper Company at Mullan, Idaho, the plant being started April 10, 1914. This was the first Callow plant ever erected and was an instantaneous success. Since that time the pneumatic process has been adopted by nearly all the other mines treating lead and lead-zinc ores in the Cœur d'Alenes, notably the Caledonia, Bunker Hill and Sullivan, Gold Hunter, Morning, Hercules, and others. The plant erected by Callow for the National Copper Company had eight regular rougher cells and two cleaner cells, treating some 500 tons in 24 hours with a consump-

[7] *Mining and Engineering World,* Sept. 11, 1915, p. 405.
[8] *Bull. A. I. M. E.,* Dec., 1915, p. 2321.

tion of as low as 0.13 pound of refined pine oil per ton. The Callow scheme finds favor in the district for the flotation of slimes and fine sand.

The surface tension tube of A. P. S. Macquisten, patented in 1904, was adopted by the Federal Mining and Smelting Company for operation at its Morning mill at Mullan in 1909. The operation at this place had been fairly satisfactory, but, as the capacity of a single cell is low and as the process is not well adapted to the treatment of slime, froth flotation is more to be recommended.

The new plant of the Hunter Mining Company[9] at Mullan, according to recent figures, was destined to pay for itself in about three months' time. Under the old scheme of concentration the mill recovery was only 50 to 60 per cent.; with flotation as an adjunct the mill is recovering 90 per cent. The flotation process at this place consists of nine Callow rougher machines and three cleaners. Four roughers and two cleaner cells were working in March, 1915, producing from 15 to 16 tons of a 50 per cent. lead concentrate from 160 tons of feed. The oil consumption was low, about 0.33 pound per ton.

Montana.

One of the most remarkable and efficient flotation plants in the country is that of the Butte and Superior mill at Butte, Mont., operating on a lead-zinc ore. The early experiments of James M. Hyde, conducted at Basin, Mont., led to the introduction of flotation at the Butte and Superior mill. A 1000-ton-per-day plant is working on the treatment of a zinc middling product as an adjunct to concentration with tables and other mill apparatus. The original recovery was only 60 per cent., but with the flotation end of the scheme operative this has been increased to 91 per cent. and more. This mill now uses the so-called Janney frothing machine, and for that reason the company is involved in legal controversy with the Minerals Separation, Ltd., the latter holding that the Janney cells infringe the Minerals Separation patents. No decision has as yet been rendered.

In this flotation process the pulp passes through agitators and thence to a bank of five flotation machines operating in parallel. The first rough concentrates are recleaned, and also the first tail-

[9] *Mining and Engineering World*, March 6, 1915, p. 460.

ings; a system of *clean and reclean* operates with the production of clean concentrates, a middling product, and tailing; the middling is returned to the system. The 55 flotation machines are supplied by six agitators through a distributing system. The frothing is performed in mill temperature solution with pine oil as the collecting element; copper sulfate and sulfuric acid are also added.

A notable installation, also, is that at the Timber Butte mill,[10] which receives ores from the Clark Elm Orlu property. Analysis of this ore shows 20 per cent. Zn, 1.5 to 2.5 per cent. Pb, 0.8 per cent. Cu, 7 to 8 ounces Ag, and 20 to 80 cents in gold. The mill process is a combination of water concentration and flotation. The coarse flotation concentrates are treated on tables in order to remove the lead and iron and produce a marketable product. Mill slimes from an Akens classifier are settled in a Dorr thickener tank, and the prepared pulp then fed to the flotation units. The flotation process is that licensed by the Minerals Separation, Ltd.; there are 8- and 11-cell machines with 150 tons and 600 tons capacity respectively. Recovery has been as high as 98 per cent. The average daily production consists of 110 tons of zinc concentrates, and also lead concentrates of a 50 per cent. grade carrying considerable silver.

Another plant, in partial operation, is the 800-ton-per-day plant of the East Butte Copper Mining Company. The Janney type of frothing machine is in use for the treatment of second-class ore and dump tailings.

The large plant recently constructed by the Anaconda Copper Mining Company at Anaconda,[11] Mont., is a noteworthy development in this state. The old mill is being remodelled and the flotation process being added to each of the mill sections; each section has a capacity of 2000 tons of feed per day. Each section of the flotation plant has four Minerals Separation machines, 15-cell type; the froth from these machines was cleaned in six Callow pneumatic cells, but the pneumatics have been abandoned and only one clean concentrate is now made. The reagents used in the flotation are: about 6 to 8 pounds of 50° B. sulfuric acid per ton of feed, plus 2 to 3 pounds of kerosene-sludge acid, and 0.5 to 1 pound of

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[10] *Mining and Engineering World*, Jan. 1, 1915, p. 29.
[11] *Mining and Scientific Press*, Aug. 28, 1915, p. 312.

wood creosote. Part of the wood creosote is added to the Hardinge grinding mills, and the remainder to the Minerals Separation units. The pulp is heated to about 70° F. The flotation concentrate is thickened in Dorr tanks and dried in Oliver filters.

Utah.

The flotation work in Utah centres about the United States Bureau of Mines and the General Engineering Company in Salt Lake City. The experimental work at the Bureau of Mines, under the direction of Mr. Dorsey A. Lyon, has contributed much to the scientific knowledge and working technic of the process. A new mill has been installed by the Utah Leasing Company[12] at Newhouse, Utah; this is a 500-ton plant, built to treat about 1,000,000 tons of tailings from the Old Cactus mine. The ore is fed to Hardinge pebble mills connected in closed-circuit with Dorr Simplex classifiers; 65-mesh material is treated in the Minerals Separation flotation machines. The oil, most of which is added to the Hardinge mill to get the benefit of the resulting agitation, is a coal-tar creosote—Barrett No. 4—combined with a kerosene acid-sludge from Nicols, Calif.; this oil gave the best results.

Elsewhere.

In California the plant of the Engels Copper Mining Company[13] is operating under Minerals Separation patents and licenses. This plant is interesting, as it is the only one in which no other process than flotation is used. The ore was not amenable to ordinary wet concentration, but is being successfully treated by flotation. A 12-cell Minerals Separation plant with a capacity of 150 to 200 tons per day is producing a 40 per cent. copper concentrate from a mill feed averaging less than 4 per cent. Cu. The flotation feed is of considerable fineness—65 per cent. of it will pass 150-mesh and only 5 per cent. remains on 100-mesh. The oil consumption is low—about 0.4 pound per ton of ore; half of the oil is fed to the tube mill and the remainder to the cells of the frothing machines. The recovery exceeds 84 per cent. The concentrates containing from 10 to 12 per cent. moisture are shipped to the Garfield smelter near Salt Lake City. Another California

[12] *Mining and Scientific Press*, Dec. 11, 1915, p. 889.

[13] *Ibid.*, July 31, 1915, p. 167.

installation is the mill of the Mountain Copper Company at Keswich; this mill is using the Minerals Separation process and has a 250-ton capacity.

That flotation has penetrated the Orient is shown by the plant of the Mitsui Mining Company [14] at its Kamioka mine in Japan. This mine has a yearly output of some 10,000 tons of an ore averaging 10 to 16 per cent. Zn and 3 to 4 ounces Ag. The concentrating plant produces an argentiferous lead concentrate, a zinc concentrate, and a zinc middling; this latter receives treatment by flotation. At this place an acidulated (H_2SO_4) solution is kept at 80° to 85° C., into which a heavy oil is introduced with a pulp ratio of 2 to 1; 29 pounds of 54° B. H_2SO_4 are used per ton. The best recoveries have been obtained on fine material; *i.e.*, 50- and 100-mesh.

The main amount of work with flotation in Nevada has been experimental and has been done at the mill of the Nevada Consolidated Copper Company, embodying mainly the practice of the Inspiration and Ray Consolidated plants already referred to. This work having not progressed further than the experimental stage as yet, no data are available. In New Mexico, flotation processes have been added to the plants of the Chino Copper Company at Hurley, using Janney machines, and at Tyrone, where the Burro Mountain Copper Company has determined the amenability of its slimes with a 500-ton mill and is now constructing a 1000-ton plant. At Chewelah, in Washington, the United Copper Mining Company has a flotation plant in successful operation on slimes.

Flotation [15] has been an active factor in the mining industry of Colorado for a few years, and flotation plants are in operation at such places as the Hudson mill and Newton mill at Idaho Springs, the Sunnyside mill at Eureka, Gold King Leasing Company at Silverton, and others too numerous to mention. In Tennessee, plants are in operation at Ducktown and at the Mascot mill of the American Zinc, Lead, and Smelting Company. This company is about to enter more actively into the field, particularly in Joplin, Mo. A Minerals Separation process has been practised at Britannia Beach, British Columbia, by the Britannia Mining

[14] *Mining and Scientific Press,* Sept. 4, 1915, p. 347.

[15] *Mining and Engineering World,* Jan. 1, 1916, p. 1.

and Smelting Company. The plant of the Braden Copper Company at Sewell, Chile, South America, is an 8-cell Minerals Separation process floating copper sulfide.

III. OILS IN FLOTATION.

The importance of oils [16] in flotation work can scarcely be overestimated, since most or all of the different processes have come to the use of oils. Since almost any kind of oil may be used to effect a separation of the finely-divided sulfides from the gangue, it is not surprising that the number of different oils, which have been tried experimentally and commercially, is almost without end. The present tendency is to determine by trial a suitable oil mixture for a given ore. It is found that coal-tar products are particularly efficacious in the flotation of copper ores, but are not so good for lead and zinc. In the flotation parlance, oils are divided into two kinds; namely, (1) frothing oils and (2) collecting oils. There may be a further classification of each of the above into such types as mineral oils, animal oils, and vegetable oils. One oil in itself may combine both the properties of collecting and frothing, so that at times there may be difficulty in stating whether an oil is a frothing oil or a collecting oil.

1. *Frothing Oils.*—A number of oils have been successful frothing oils, and this includes the pine oils—steam refined and crude—cresylic acid, and turpentines and other pyroligneous products from the distillation of woods. The coal-tar phenols and most or all of the essential oils are efficient frothers. The essential oil of the *Eucalyptus globulus* finds wide application as a flotation oil in Australia on account of low cost; it would be prohibitively costly to use it in this country. Pine oil is unquestionably the best frothing agent known, but has recently become prohibitively costly, and the same is true of cresylic acid. In general, the essential oils give a coherent froth and satisfactory extraction.

2. *Collecting Oils.*—The mineral and tar oils have a marked selective action on the mineral sulfides and are generally poor frothers. The mineral oils used in flotation include crude petroleum, refined oil, gasoline, kerosene, creosol, and coal tar and coal-tar creosotes. Oils derived from the destructive distillation of

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[16] *Mining and Scientific Press*, Sept. 25 and Dec. 4, 1915.

wood, such as wood creosotes, pyroligneous acid, and similar products, are good flotation oils from the standpoint of cost and efficiency. Coal tar has the property of stiffening a weak froth, and may be employed as a mixture with 10 per cent. pine oil.

Recent commercial practice demonstrates that acid may be eliminated from the pulp solutions if a suitable oil mixture be determined. The same results can evidently be obtained in an alkaline or neutral pulp as in an acid one. The flotation experts employed in the erection of plants have come to the practice of using, in the work at hand, the oil available. An instance is given where power is generated at a certain plant using Deisel engines, and the practice has become so fixed now that the same oil is used for flotation as is used in the Deisel equipment. Evidently no given oil or combination of oils will perform effective work on all ores; it is a particular problem for each ore to find the most suitable oil mixture.

It is the conviction of at least one large company supplying oils for flotation consumption that there are too many oils on the market, and that a medium-price oil (20 cents per gallon in tank cars) will be the frothing element which large consumers will favor. It is the consensus of opinion that pine products are essential to the production of good froth, and are also good selective oils. Considerable difficulty is experienced by the consumers in the duplication of orders, for it seems as though the oil companies cannot or do not furnish the same oil on repeated orders. Why this condition of affairs should obtain is not apparent.

IV. MISCELLANEOUS CONSIDERATIONS.

The present practice favors the ball mill for grinding the tailings or other material to be floated, as the bulk of the feed is thus reduced to slime, which is the ideal feed for froth flotation. The use of Dorr thickening tanks for thickening the pulp, placed in closed circuit with the grinding mill, seems to be a present tendency for a future standard practice. The fact that flotation can and does work best on slimes has removed the old dread of mill operators for making slimes in the wet concentration; this will result in some minor changes in mill practice. Before shipment to smelter or other market, flotation concentrates must be dewatered by filters to a moisture content of about 8 to 10 per cent.; otherwise, heavy freight bills are incurred which might consume

the profits. The moisture content cannot be too low in the case of long shipments, or heavy dusting losses will take place. The so-called Oliver filter will reduce the moisture to 8 per cent. or less, and is preferable to the pressure type of filter on account of the excessive operating cost of the latter. Filters of this type are employed by the Anaconda Copper Mining Company, the Inspiration Copper Company, the Timber Butte Milling Company, the Federal Mining and Smelting Company, and other large operators.

In smelting flotation concentrates for the recovery of the values therein, the ordinary practice is adhered to, pendent on the nature of the values—zinc, copper, lead, etc. The best practice recommends drying the concentrate before charging into a reverberatory or other furnace; *i.e.*, it is best to charge a hot calcine. If it is desired to reduce the sulfur content, calcines can be made in the ordinary McDougal or Wedge multiple-hearth furnaces.

RÉSUMÉ.

Generally speaking, the mechanically- or air-agitated machines require fine material for successful performance; *i.e.*, 60-mesh or finer. In other words, most of the flotation processes are preëminently suited to the recovery of slimes. It would seem as though the flotation process should be used as an accessory unit in wet concentration, as an all-sliming plant, with few exceptions, is not an economic possibility in this country. The matter of rougher and cleaner cells is strictly a local consideration and must be determined separately for each individual plant. Two cogent factors enter into the solution of this problem; to wit, richness or leanness of the slime feed and proximity or remoteness from smelters. The dual, *clean and reclean* method, was tried at Anaconda and finally abandoned in favor of the single cleaning method.

In the Callow [17] process the pulp density may vary from 2.5 to 1 on a strictly sand feed up to 7 to 1 on a slimy feed. The particular density of feed is not a matter of such vital importance as is the necessity of a uniform density of pulp supply. In this process the quantity of oil used increases in proportion to the increased volume of pulp, and is independent of the solid content. Hence there is a dictum which says that the pulp should be run as thick as possible so long as other conditions operate satisfactorily.

[17] *Bull. A. I. M. E.*, Dec., 1915, p. 2321.

The advantages of the pneumatic process are: greater recoveries, less oil, greater simplicity of operation, and less skill required to operate. It is known that a pneumatic froth is much more ephemeral than that made in mechanically-agitated machines, and this is an advantage in handling the resulting concentrates.

Universities teaching mining and allied subjects, particularly some of the state institutions in the West, having experimental research bureaus in connection, have taken up the matter of flotation research, as well as the determination of the amenability of ores and mill products, the subject of flotation oils, and other things relative to this process. The present and recently-formed coöperative plan of work among the United States Bureau of Mines, the State Department of Chemical Research of the Kansas State University, and the Mine Experiment Station of the Missouri School of Mines should have considerable bearing on the ultimate solution of some of the present flotation problems. The work at the Kansas Bureau [18] and elsewhere has determined the amenability of the slimes of the Joplin district to flotation, and great savings could be effected were flotation plants installed in that district. The yearly loss in slimes in the Joplin lead-zinc area approximates $11,000,000, which could be saved were flotation plants installed, thus contributing to the resources of the country.

Broadly, flotation has now reached a stage so as to find widespread commercial application. It is a noteworthy fact in the history of milling that such an apparently simple process should have such a ramified development in such a short time. There can be no question that flotation in due time will be a necessary adjunct in all the mills in the mining industry. Already the process has added greatly to the world's wealth. From its inception to date it has produced about $20,000,000 in silver, $1,700,000 in copper, $612,000,000 in spelter, and $19,800,000 in lead.

The Use of X-rays with Intervals of Red Illumination. J. BOYER. (*Scientific American*, vol. cxiv, No. 8, February 19, 1916.) —In the present practice of X-ray surgery, the surgeon, manipulating his instruments under the fluorescent screen, is compelled to work in darkness, although all the while he exposes himself to the harmful effect of the X-rays. On the other hand, the surgeon working in bright light is obliged to depend on an assistant, who, alone in a position to see the X-ray images on the screen, guides him in his

[18] *Metallurgical and Chemical Engineering*, Nov. 15, 1915, p. 847.

work. Because of the drawbacks of both these methods, many surgeons prefer to perform their work without the aid of the X-rays. A new method, worked out by Prof. J. Bergonie, of Bordeaux, France, based on the law of simultaneous contrast of colors, will undoubtedly cause many surgeons to resort to the use of X-rays in their work. The principle involved, originally formulated by Chevreul, is best demonstrated as follows:

If the eyes rest for several moments on an object of a certain shade, after which they are turned away, the eyes retain for a few instants the complementary color of the subject previously observed; this phenomenon being due to the persistence of luminous impression on the retina of the eye. For example, observe for a few moments a red flower and then turn to a disc of white porcelain. The disc will appear to be of greenish tint. As Chevreul has demonstrated, this phenomenon is one of the reasons for the intensification of a color impression when two complementary colors are placed in juxtaposition. Modifying the experiment by taking a disc of greenish shade, it will be observed that the green is intensified by the green impression made on the retina of the eye by the red vision. Likewise, if the eyes are brought to bear on the red flower, its color will be increased by the red impression given to the retina by the green disc. The two colors reciprocally improve each other, and Professor Bergonie has made use of these facts to facilitate the task of the surgeon who, in the course of an operation, utilizes the X-rays to see through the body of his patient.

Professor Bergonie illuminates the operating room by means of an intense red light of great purity, in which there is not a single green or yellow radiation such as are emitted by the fluorescent screen of the X-ray apparatus. Due to the effect of contrast, the sensibility of the retina of the surgeon and his assistants is conserved and even increased during the period of surgical intervention using the red light. Heretofore the employment of normal illumination during intervals has caused not only much eye fatigue to the surgeon and his aids, but has resulted in lengthening operations because of the time necessary to accommodate the retina of the eye to the change. To state the Bergonie method definitely: The active phases of an operation are executed under red light, while the X-ray examination of the patient's body in the region of the operation are made in the greenish light of X-rays for an interval seldom exceeding 30 seconds.

For several months past Professor Bergonie has been applying his method in the hospital of Bordeaux, where it has given much satisfaction. The luminous dome which furnishes the red light is placed directly over the operation table and is of about the same dimensions as the latter in order to avoid shadows. The dome contains 20 lamps of 25 candle-power each, the rays of which pass through red glass. Although the illumination thus furnished is admittedly poor, the surgeons declare it is sufficient for their purpose.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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LIGHT PRODUCTION AS SEEN IN WORMS.

LIGHT production has been reported in the Turbellarian worm, *Typhlophana retusa,* by Viviani, but Mangold regards the observation as not complete, and the case is still doubtful. He takes the same view of Giglioli's report on the lighting of several species of *Sagitta.* The writer feels that both these reports, especially that concerning *Sagitta,* should not be dismissed until a much more careful and wider survey of the field has been made. *Sagitta,* in its habits of a surface pelagic form, is numbered among the animals that are especially liable to illuminate. That the organism possesses a stratified epithelial surface, instead of the simple glandular epithelium of most worms, does not preclude the possibility of its having some kind of light-producing power.

Similar reports concerning a rotifer, *Synchæta baltica,* seem to stand in the same position.

Among the more conventional or higher types of worms we find five chief types of luminosity, the first four of which are polychætes and the last type are oligochætes. These types are:

1. Syllids and terebellids, several members of each with a small amount of rather generally distributed luminous tissue. *Polycirrus aurantiacus* shows a general luminosity. In *Odontosyllis* these tissues are found to be specialized into definite organs at several points.

2. *Chætopterus,* a form in which the tissues and organs are much more highly organized and specialized.

3. The polynœid worms, in which the majority of the members have a very strong, efficient, and highly-specialized lighting system.

4. *Tomopterus* and its allies. Here there still remains a little doubt as to the lighting power, but the organs in question (some have called them eyes) are highly specialized and in unusual positions.

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* Continued from page 556, April issue.

5. Certain oligochætes, as *Lumbricus,* etc., in which light has undoubtedly been seen coming from parts of the body, the only question being if it is really derived from the animal's body or from bacteria or fungi that they have eaten or that are parasitic upon them.

The syllid and terebellid worms and many related forms show the simplest kind of luminosity. The power is almost restricted to those that live in burrows or tubes and whose body is provided with a bunch of ciliated filaments. As examples of the syllid group we will discuss a species of *Polycirrus auranticus* from the coast of England, and then the terebellid form, *Odontosyllis enopla,* in which the light production is more highly specialized and has a known purpose.

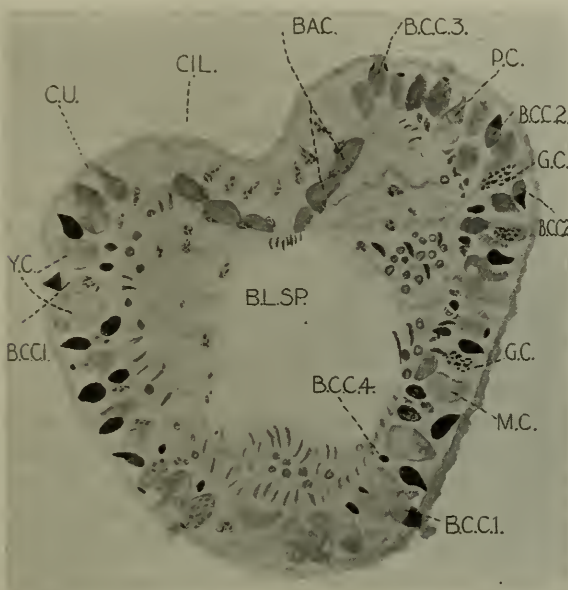
POLYCIRRUS AURANTICUS.

The particular *Polycirrus* which we are describing is a small, thick, red-colored worm living among the rocks and weeds near low-water mark. From its head protrude two large bunches of long, fleshy tentacles. Each tentacle shows in cross-section (Fig. 1) a core of connective tissue and muscle, and contains blood-vessels lying in its entire length. The blood is but little removed from the outside water in which the tentacles lie, and, although the tentacle is not counted as a gill, the exchanges of oxygen and carbon dioxide are effected in the large amount of blood-vessel surface thus exposed. The tentacle also has a ciliated groove by means of which food is collected. The animal lies in its habitat with these tentacles extending out in all directions on the surrounding sea-bottom. The body is blood red and the tentacles are orange in color. It is not eaten by fish on account of a poisonous or distasteful odor emanating from its body. When the animal is disturbed, especially when the tentacles are injured or rubbed in any way, these tentacles show a rather weak violet-blue light which flashes out strongest at the tips of the tentacles and less strong as one looks toward their proximal ends. Practically no light is seen under ordinary conditions in the fourth part of their length nearest the head to which they are attached. When the animal is stimulated in some excessive or extreme manner a weak light may be seen on most of the body for a short time. When the animal is attacked by any fish it curls its body up into a ball and wraps the tentacles around this ball. It is the tentacles that are distasteful to other animals and not the body, if the

tentacles have first been cut off. We can thus see that the light acts in the same way in the darkness as the orange color of the tentacles does in the daytime. It is a warning signal and a protection to its owner.

Looking again at the cross-section as shown in Fig. 1, we see that the outline of the tentacles is not round. One side is deeply indented by a groove which follows the whole length of the structure from point of origin on the head to tip. All parts of the tentacle are covered by a strong, simple epithelium. In the groove the cells are furnished with well-developed cilia, and the cells are otherwise undifferentiated (Fig. 1, *cil.*). It is evident that we may not look for the source of the light here.

FIG. 1.



Transverse section of one of the tentacles of the worm *Polycirrus auranticus*. *cil.*, ciliated cells of feeding groove; *b.c.c.*1, black-capped cells (light-cells); *b.c.c.*2, younger black-capped cells before secretion; *b.c.c.*3, black-capped cell discharging through ruptured cap—cap cut in longitudinal sections; *b.c.c.*4, youngest stage of secretion reservoir in a black-capped cell; *m.c.*, mucous cell; *y.c.*, yellow cells (poison-cells); *g.c.*, granule-cells; *ba.c.*, basal cells (yellow): *cu.*, cuticle; *p.c.*, proximal, large granule-cells; *bl.sp.*, blood-space.

The remainder of the epithelial cells, however, lining the outer sides of the tentacle show several kinds of marked differentiation of their outer cytoplasm. In general they form a row of even

height, covered continuously with a soft, elastic cuticle (Fig. 1, *cu.*). The nuclei lie rather closer than is usual to the proximal ends of the cells and are large, deep staining bodies with a good, strong chromatin pattern. They lie so closely together that if they are all epithelial nuclei the cells must be very narrow and lie closely together. Only a few of the nuclei are shown in the figure. The lateral walls do not show plainly enough to decide the exact width of the cells.

Many of these cells appear to have no distal secretion areas or no secretion inclusions in their cytoplasm. In others, however, there are very large, easily-stained or observed inclusions, which will be discussed as follows: First we find an easily-identified cell containing a large mass of yellow substance, clearly a distal secretion reservoir of some specific material. The mass has the coarse, reticular appearance of many ripe mucous cells, and its distal half shows the richest yellow tint, the proximal edge being almost without this color (Fig. 1, *y.c.*). The nuclei belonging to the different types of cells appear to be of one kind, and it has not seemed possible to associate any particular kind of nucleus with this particular secretion reservoir. Such determination can only be made by means of carefully-dissociated preparations in which the single cells can be viewed alone.

It is evidently these cells that give to the tentacle its orange color. Also, since this color is confined to the tentacles and since no other type of secretory cell appears to be confined to the tentacle, we may assume with considerable safety that these yellow cells also are the source of the offensive taste or odor that protects the worm and which is found only in connection with the tentacles, as Dr. Garstang has shown by his experiments at the Plymouth Zoological Station.

We are now confronted with as many as seven other kinds of cells in this epithelium, some of which types most probably represent different growth or regeneration stages of the same structure. These will be described in an order which, in part, possibly shows these relationships.

The second kind of cell to be described may be termed the gray, black-capped cell, from the appearance of the secretion reservoirs (Fig. 1, *b. c. c.* 1). These reservoirs are distal in the cell, the smaller ones often lying at an unusual angle in the cell (Fig. 1, *b. c. c.* 2). This may, perhaps, be taken to indicate an unripe

stage. The proximal part of the body of this structure is of a homogeneous gray color (Bouin's fixation, iron hæmatoxylin stain). If granular, the granules are so small as to form a homogeneous mass. The distal part is somewhat pointed and stains, in this preparation, a jet black. When full sized, this point rests against the cuticle, and in a certain number of the cells the observer can see a plug of the secretion protruding from a pore in the cuticle, as in Fig. 1, *b. c. c.* 1. These cells, from their abundance and visible discharging activity, appear to the writer to be the light-cells, although lack of opportunity for experimental study leaves the matter in some doubt. An important point in connection with the discharge of this cell is shown at *b. c. c.* 3, where a fortunate cutting of the section shows that, in discharging, the secretion ruptures the black cap at its point: also, that this cap is really a thin cap and not a solid point. From its staining reactions it appears that this cap may be of a muscular nature, although it is almost equally probable that it may be of some inert, connective substance, as of keratin or an allied material.

The third kind of cell, as distinguished by its secretion reservoir, is of a solid black color and nearly always of the same shape as the black-capped cells. Many of these cells are present in Fig. 1, *b. c. c.* 2, and, from their form and position, one must take them to be younger stages of the black-capped cells. Very early stages of the development of the gray, non-staining proximal end were not seen, but some stages of half-and-half were found, and from that up to the large gray cell with a very small black cap. Such an atrophy of a muscular or keratin cap would be an ideal way of retaining the light-secretion until ripe, when a slight pressure by nerve stimulus would discharge the contents in whole or in part. Both the appearance of the cells and the visible evidences of the discharge seem to indicate that the secretion is not all discharged at one time and that it is a rather thick and tenacious material.

The fourth variety of cell seems to be an even earlier stage of development of this same light (?) cell. The secretion bodies that represent this unit appear deep down in the basal part of the epithelium, and as they increase in size they move distally, probably through the cytoplasm of the cell. All stages of this development may be seen in the epithelium, from the small, oval bodies at the base, not larger than the nuclei, through the successively larger bodies up to the third form and, finally, the second sort described

above as the finished light-cell. Fig. 1 shows a number of these bodies, marked *b. c. c.* 4.

We now turn to another kind of cell, a fifth cell in our list, that bears a considerable resemblance to the black-capped cells, except that its secretion reservoir is filled with distinguishable granules. These granules are of medium size, and the secretion bodies are placed distally, with a secretion pore in the cuticle. No discharge masses have been observed and the black cap is missing, although traces of it are visible in a few cases (Fig. 1, *m. c.*). These cells may be mucin cells. The granules hardly indicate this, as real mucin cells usually pass from the granular form of development into the dissolved mucous form before discharge. The probability that they are mucin cells, however, is heightened by the fact that no mucous cells of the usual type are present, and, as in *Lumbricus,* the mucin granules may be thrown out and only turn into mucus after reaching the water. These worms, like most other, seem to have an abundant supply of mucus in life.

A sixth distinct kind of cell shows a large body of secretions extending from the surface almost down to the proximal end (Fig. 1, *g. c.*). This secretion consists of large black granules, well separated from one another and with a few finer ones in between the large ones. But few of these cells occur—one or two in each transverse section. The form, size, and staining reaction of the granules and the elongate shape of the secretion reservoir seem to mark them as a different cell from any other.

The seventh variety of cell is also a coarse, granular one (Fig. 1, *p. c.*). These cells are remarkable for the large size and proximal positions of the secretion organs. Those bodies lie deep in the epithelium, with their proximal ends lying against the basal membrane. The nucleus, in consequence, lies on the side of the secretion body, and this body has the same pear-shaped form that the black-capped cells have, except, perhaps, it is a trifle longer and narrower. The granules are very large and no longer round, owing to their mutual pressure. How this secretion body opens to discharge its content is not apparent, unless the acute point from which the discharge takes place opens into some invisible channel between two cells. Some such arrangement surely must exist, as this is undoubtedly a gland-cell.

But one more kind of gland-cell remains to be described, an eighth variety, that lies flattened out against the basement mem-

brane without any imaginable mode of egress to the exterior for its secretion. The content of this cell is a reticular mass of gray material with a light-yellow tinge. In some cases the gray is very light, when the cells become almost transparent. These cells lie particularly thick under the ciliated epithelium in the groove (Fig. 1, *ba. c.*). They may be cells that elaborate some material that is passed back into the blood, some kind of a ductless gland. It would be hard to prove this with no other evidence than the position of the cells.

Thus we have a number of different sorts of gland-cells in the epithelium of the tentacle of this little worm. It may be easy to do the necessary experimental work to determine the functions of the various kinds, or it may be exceedingly difficult. It would prove an interesting problem in any event.

ODONTOSYLLIS ENOPIA.

This interesting worm was observed at Bermuda by a number of naturalists, who spoke to the writer about it, including Dr. E. L. Mark, Dr. L. R. Cary, Dr. E. Linton, and many others. It was made a particular study of by Dr. T. W. Galloway and Paul S. Welch, who described its habits in regard to the power of light production and thus placed it upon the very small list of luminous organisms the purpose of whose light we understand.

This worm is said never to light except in the breeding season, and then only when in the act of depositing its sperm and eggs. The breeding season occurs in summer time, during the summer months at periods that suggest the lunar month. Thus Galloway and Welch report them in 1904 as occurring at July 4, July 30, and August 23. Possibly they also occurred in early June and in September at the appropriate lunar period. This reminds one of the other worms, especially the various species of Palolo worm, whose reproductive periods are regulated by the phases of the moon. Each of these reproductive periods in *Odontosyllis* also occurred, in a lesser degree, for a day or two before and after the dates named.

The most exact timing of the phenomena, however, takes place with reference to the time of day. While the Palolo spawns at dawn, this worm appears very promptly in the early evening, just as dusk is becoming pronounced. The daily period lasts in each case for only about twenty-five minutes, no worms being seen after

a half hour has elapsed since the beginning of the spawning process. We may well quote Galloway as to the appearance of the process as he observed it:

"In mating, the females, which are clearly swimming at the surface of the water before they begin to be phosphorescent, show first as a dim glow. Quite suddenly she becomes acutely phosphorescent, particularly in the posterior three-fourths of the body, although all the segments seem to be luminous in some degree. At this phase she swims rapidly through the water in small, luminous circles two or more inches in diameter. Around this smaller vivid circle is a halo of phosphorescence, growing dimmer peripherally. This halo of phosphorescence is possibly caused by the escaping eggs, together with whatever body fluids accompany them. At any rate, the phosphorescent effect closely accompanies ovulation, and the eggs continue mildly phosphorescent for a while. The fact that the luminosity is known at no other time is further suggestive that it is produced by the material which escapes from the body cavity. If the phosphorescent glands are external, as the histology of the epidermis at least suggests, the discharge of the glands is closely correlated with ovulation.

"If the male does not appear, this illumination ceases after ten to twenty seconds. In the absence of the male the process may apparently be repeated as often as four or five times by one female, at intervals of ten to thirty seconds. The later intervals are longer than the earlier. Usually, however, the males are sufficiently abundant to make this repetition unnecessary; and the unmated females are rare, if they are out in the open water. One can sometimes locate the drifting female between displays by the persistence of the luminosity of the eggs; but the male is unable to find her in this way.

"The male appears first as a delicate glint of light, possibly as much as ten or fifteen feet from the luminous female. They do not swim at the surface, as do the females, but come obliquely up from the deeper water. They dart directly for the centre of the luminous circle, and they locate the female with remarkable precision when she is in the acute stage of phosphorescence. If, however, she ceases to be actively phosphorescent before he covers the distance, he is uncertain and apparently ceases swimming, as he certainly ceases being luminous, until she becomes phosphorescent again. When her position becomes defined he quickly

approaches her, and they rotate together in somewhat wider circles, scattering eggs and sperm in the water. The period is somewhat longer, on the average, than when the female is rotating alone; but it, too, is of short duration.

"So far as could be observed, the phosphorescent display is not repeated by either individual after mating. Very shortly the worms cease to be luminous and are lost. Often they give the appearance of sinking out of sight; however, this appearance is negatived by the fact that I have caught both sexes at once by timing the current and dipping down stream as much as six or eight feet from the point of latest visible phosphorescence. Sometimes as many as two or three males seem to take part in one mating.

"The females caught and examined immediately on becoming luminous are full of eggs. Those caught after three or four displays, or after copulation, are largely empty of eggs; yet the different segments of one worm will differ widely in this particular. Eggs are often caught among the setæ and at any other points where they can be held.

"Specimens in confinement after copulation may be aroused into mild phosphorescence for at least an hour." Fig. 2 represents the appearance of a female and three male *Odontosyllis* at mating time.

Let us now examine the structure of the worm and try to determine the source of the luminous material. The writer scarcely can agree with Galloway's suggestion that this substance can come from the eggs or the body fluid that accompanies them. All our studies go to show that light comes only from a definite luciferine, and that this luciferine must be elaborated by specific cells organized for this purpose. Furthermore, such cells appear to have been in every case some form of epithelium or epithelial glands or derived from an epithelium. In this simply-organized worm we would expect to find such cells lying in the external epithelium and scattered pretty generally over the surfaces that have been observed to light when the animals are breeding, as has already been described.

Galloway describes two types of gland-cells in the epithelium of the worm, and makes the suggestion that the type designated by him as "regular" gland-cell is the origin of the creature's luminosity. This regular gland-cell is marked by its form, that of a

truncate cone with the larger end placed distally (Fig. 3, *A*) and with its smaller proximal end reaching only about two-thirds of the way down to the basement membrane. The inner end of the cell's cytoplasm has a reticulated or alveolar structure, while the outer part has a proximo-distal striation. The nucleus is large, of the glandular type, and is situated in the middle of the cell.

The other type is so evidently a mucous gland-cell that we will

FIG. 2.

The mating of *Odontosyllis* at Bermuda as seen from below the surface of the sea. Female worm describing rapid circles and twists on the surface and throwing off eggs and light material. Two males attracted by the light and approaching, themselves lighting, to fertilize the eggs. (Drawn by E. Grace White after the descriptions of Galloway and Welch, Cary, Linton, and others.)

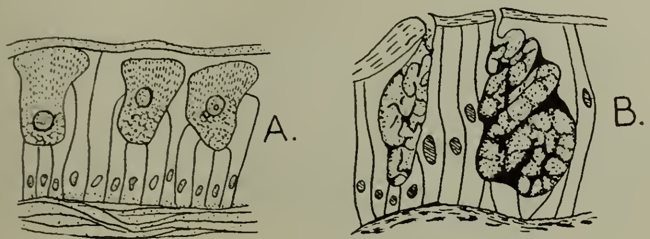
not describe it beyond saying that its content is a reticulated mass that answers all tests for mucin (Fig. 3, *B*).

The writer, after reading Galloway's beautiful description of the luminosity of this worm at breeding time, was not satisfied that the "regular" gland-cells, or even the twisted or mucous cells, were capable of producing so much light in so short a time, especially of throwing off a luciferine that glowed for an appreciable time in the water after having become separated from the body. We have seen many instances of organisms where the light

material was a fluid and where it was impossible to separate it from the body in a luminous state. The polynoid worms are examples of this, also the worm *Polycirrus,* as well as many other organisms. So it became necessary to look for a gland in which some considerable amount of luciferine, in the form of definite granules of a considerable size, could be formed and stored, to be thrown out to produce light much in the same manner as *Pholas* and *Chætopterus* do.

These glands, he believes, are to be found as modifications of the setegenous glands in the parapodia of this worm, both in the male and in the female (Fig. 4, *l. g.*). It still remains to actually see the light and to prove this working hypothesis true, but the structure and staining power accord so well with the many other

FIG. 3, A AND B.



Two bits of body epithelium from *Odontosyllis*, showing two kinds of gland-cells as described by Galloway and Welch. *A*, regular gland-cells (light-cells?); *B*, mucous cells. (After Galloway and Welch.)

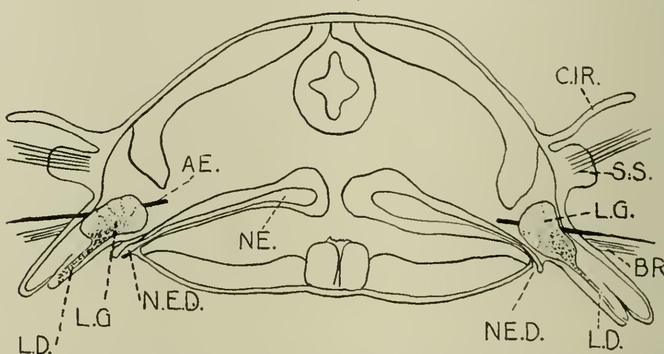
well-known light organs that it seems most probable that these are the real and main light organs, although it is possible and even probable that a few scattered epithelial cells—for instance, the "regular" gland-cells of the skin—may light also at breeding time or even at any time when they may be stimulated.

In Fig. 20 of Galloway's paper (see Fig. 4) it can be seen that the parapodium consists of an upper notapodium bearing a cirrus (*cir.*) on its upper lobe and with swimming bristles (*s. s.*) and a supporting aciculum (*ac.*) projecting from its lower lobe. The ventral portion of the parapodium or neuropodium consists of an upper lobe with a bunch of fine bristles and several acicula projecting from it, and a lower lobe through which the nephridial outlet passes. The basal portion of this neuropodium is occupied by a large gland which in other worms is used to produce the bristles or setæ. In this worm it appears to be devoted in part

to the secretion of the light substances. The real setegenous portions of the gland are closely applied to, and surrounded by, the light-producing portion. Still, such portions as belong to the bristles specifically are quite easy to differentiate from the large light-producing lobe, both by their staining reactions as well as by their structural relations. This gland empties by a duct (*l. d.*) through the tip of the neuropodium.

Fig. 5 shows a view of part of a parapodium, from about the middle portion of a female worm with this gland in place. So large is its mass that Galloway mistook a lobe of it for a glandular

FIG. 4.



Line diagram of a segment from the middle part of the body of a female *Odontosyllis*. *cir.*, cirrus; *s.s.*, swimming setæ; *l.g.*, light-gland; *ac.*, aciculus; *ne.*, nephridium; *ne.d.*, nephridial duct; *br.*, bristles; *l-d.*, light duct. (Drawn by E. Grace White.)

portion of the nephridium. The nephridium, however, can be traced, as a single almost straight tube, past and through a portion of this gland, and can be seen to have no organic connection with it. The relation of the gland to the various bristles of the worm make it somewhat harder to differentiate as a luminous organ, rather than as a gland whose sole function is to produce luciferine.

The gland is formed by the recession of a number (possibly 35) of gland-cells from the epithelium of the dorsal lobe of the neuropodium. These cells retreat up into the base of the parapodium and form a single ovoid mass which varies in size in the different segments of the worm, and, according to its size, etc., is slightly modified in shape to permit of the passage through this base of the nephridial tube, three acicula and a bunch of bristles (not the swimming bristles).

All of the cells of this mass retain their glandular communication with the lower side of the dorsal lobe of the neuropodium through their ducts, which do not merge into one common duct, but, apparently, into several. The point of exit of the ducts is through a specially-arranged, muscle-free portion of the parapodial wall, and there is a surrounding ring of muscular tissue that can probably prevent the discharge of the light material from the ducts except during the breeding period. This gland should be studied at some period when the animal is not near the breeding time in order to see if this duct is entirely shut off by a growth of

FIG. 5.

View from in front of a section through part of a parapodium of *Odontosyllis* containing a light-gland. *l.c.*, light-cells; *gr.*, granular masses connected with light-cells; *en.*, accessory cell s of light-gland; *du.*, ducts of two kinds from light-gland cells; *ex.*, point of discharge of light-gland cells; *ne.*, nephridium. (Drawn by E. Grace White from a section.)

the epithelium that would have to be ruptured when the next discharge took place.

The cells that compose the gland are of two or three varieties that are well differentiated by a stain of Delafield's hæmatoxylin, and eosin or erythrosin (Fig. 5). They may be thus made to show three (or two) groups which lie approximately proximally or distally from one another and remind one much of the arrangement of the two kinds of light-cells in the mollusk *Pholas;* also, their secretions empty from the ducts in separated but contiguous streams, so that we probably have a compound gland secreting the catalytic enzyme as well as the luciferine.

The most proximal portion of the gland (Fig. 5, *l. c.*) consists of cells that are larger than the rest of the cells in the gland and have an elongate oval outline terminating at its distal end in a series of tube-like ducts (Fig. 5, *du.*) that run through the rest of the gland to empty at the end or near the end of the dorsal lobe of the neuropodium (*e.x.*). The proximal cytoplasm of this cell is massive and shows a series of fine vacuolated spaces that seem to form a branching series of channels in which the secretion of luciferine probably takes place. With Delafield's hæmatoxylin or with hæmalum this cytoplasm stains a light transparent blue and shows a single nucleus of moderate size in some part of its mass. The bodies of these light-blue, homogeneous cells form a compact, crescentic, proximal part of the gland with a smooth, rounded, proximal surface and an irregularly-toothed, distal surface where the cell masses fit into the next layer. There is still some doubt concerning these second sort of bodies: whether they were the bodies of a second set of cells or whether they were the distal ends and secretion reservoirs of the smooth blue cells. Since no nucleus could be demonstrated in them, and since the smooth blue cells did not show a clearly-defined duct, but seemed to end rather abruptly against the second sort, it is concluded, with some slight reservation, that the latter idea is the correct one.

These second masses (Fig. 5, *gr.*) are filled with a series of coarse, rounded granules that do not take the stain at all, but retain their natural light-yellow color. No undifferentiated cytoplasm whatever appears in connection with them, and they are therefore to be looked upon as the secretion reservoirs of the light-blue cells, the whole structure, with its tube-like duct, forming the light-cells of the animal. The granules extend from the cell into the ducts and so out to the openings between the hypodermal cells on the end of the neuropodium, where they discharge. These granule-filled reservoirs form a narrow zone of one or two thicknesses between their light-cells and the distal cells which form the outer zone of the gland. The granule-filled ducts of the light-cells are collected and pass in a rather distinct bundle not through but on the outer side of the gland. This does not appear well in the figure.

The third set of masses (Fig. 5, *cn.*), a distinct group of longer, narrower, and more elongate cells, are placed in the distal part of the gland and are also much smaller than the light-cells,

even without the mass of their reservoir added. These cells will be called the enzyme cells or luciferase cells. A slight doubt still remains as to whether they are for this purpose or are merely mucous glands, but they present some notable differences from the real mucous cells in the skin. The nucleus is not a flattened proximal structure, but is round and appears in the centre of the chief cell-mass. The content of the cell is granular, more finely granular than the light-cells, and with Delafield's hæmatoxylin it stains a dark blue, just as in the case of the distal layer of cells in the light organ of *Pholas*. The ducts from these cells also gather into a distinct bundle and accompany the bundle of light-cell ducts out to the point of opening on the neuropodium. Some few of the ducts sometimes get mixed with the duct-bundle of the light-cells, but this is only occasional.

It seems to the writer that here we have a very complete and efficient light-gland that accounts in every way for the bright external light shown by the worms when mating. No comparison was made between male and female, but it is thought that the glands must be very much the same in both. The large size of the light granules would readily account for the persistence of the light in the water, just as it does in *Chætopterus* and *Pholas*.

A more complete study should be made with an abundance of material and a careful physiological study of the animals in the field.

POLYNOID WORMS.

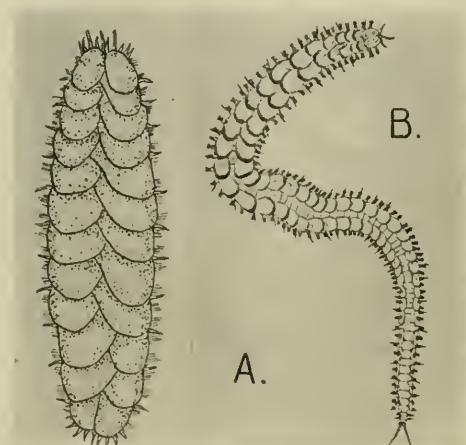
In these interesting forms most of the species are luminous. They vary in form from short, stout annelids like *Lepidonotis* (Fig. 6, *A*) to longer and more slender species like *Polynœ squamata* and *Acholœ astericola* (Fig. 6, *B*). These worms are poor swimmers, and their usual haunts are among stones and gravel and shells on the bottom of littoral regions, from low tide out to several fathoms, where they are most abundant, and to deeper waters, where some few of the species are found. A few forms are parasitic or commensal with other animals, as is well shown by the form *Acholœ astericola,* that lives only on the under surface of the arms of the brittle star *Astropecten auranticus*.

The most important structural feature of these creatures in connection with our light studies is a double row of so-called "scales" that run down the entire dorsal surface, one row on each side of the median line, with a more or less considerable

portion of the median surface of the back, between the rows, left bare. These "scales" are not such in the sense that we usually speak of such structures, as in fishes, etc., but are flattened portions of the animal's integument or body-wall, consisting of a mesodermal core covered with the reflected epithelium of the body. They are spoken of as Elytra.

Each elytrum is attached to the body by a stem of the same fleshly substance, through which a nerve and blood supply runs and is distributed mostly to the upper surface and edge of the

FIG. 6, A.



Sketch of *Lepidonotus squamata*. *B*, sketch of *Acholæ astericola* to show form. (Adapted from Kutschera.)

structure. Fig. 7 will give a good idea of this arrangement in *Acholæ astericola,* especially when one compares it with Fig. 6, in which the outer structural arrangement can be seen in a more general way.

The lighting of these worms is characteristic: like that of so many other light-producing creatures, it is a reaction to a chemical, mechanical, electrical, or thermic stimulus. But it follows certain rules that do not obtain in some of the others. Falger describes it from careful experiments in somewhat the following manner: When undisturbed the worm shows no light, but a weak mechanical stimulation, such as the slight shaking of the dish of sea-water in

which it is, results in a very weak shimmer on the edges of the scales. When the creature is gently touched with a needle or a glass rod the light becomes stronger and the luminous edge of the scale is widened. First the part touched or the nearest scales begin to shine, and the luminosity spreads rapidly, both backward and forward, from this point. Not all of the scales light evenly, but with considerable differences of intensity. Falger thought this might be due to different degrees of sensitivity or to different stages of secretion of the luciferine. The light lasted a few seconds, but a weak glimmer might follow, a second or two after

FIG. 7.

Two elytra in position on a segment of the body of the worm *Acholœ astericola*. The point of union of body and elytrum by a pedicel is indicated by the oval area. Nerve is seen rising out of body through pedicel and branching over elytrum. "Teeth" are indicated on anterior edge of elytrum and light organs on posterior half. (After Kutschera.)

the main display was over. The light was greenish-blue and so strong that it could be seen in a moderately-lighted room.

When a drop or two of hydrochloric acid was poured in the water a very intense light was produced. This appeared as a strong flash, followed by a weak but lasting display. Strong alkalies also stimulated to light production, but not so well as the acids.

A fresh worm in normal sea-water was subjected to a slow, constant rise in temperature of the water. A very weak light began with the first rise in temperature, and this light increased as the temperature rose. It was at its strongest when the water attained a temperature of 40° C. In this amount of heat the animal soon died. Another fresh worm was thrown into water

of 40° C., and after a short, strong flash of light it also died. Cold was not tried.

Electrical stimulation was the most successful means of experimenting with the light, as the animal was not permanently injured and the stimulation could be measured with great exactness. Both the direct and alternating currents were used. The wet animal was laid on a glass plate and non-polarizable electrodes were applied to its ends. When a direct current from the one-volt batteries was applied, the whole worm lighted equally, and when this current was shut off the light persisted in a weaker form until the current was once more applied, when it appeared in its strong intensity again. An instantaneous change in the direction of the current caused a bright light to appear for a moment. A current of very rapid alternation was then applied from three batteries, a combined strength of three volts of electromotive force. This gave the interesting result that the light actually followed the alternations so rapidly that it appeared to vibrate. When the current was lowered the light became less, but still followed the alternations. This went on for from twenty to thirty minutes, when the light became very weak. But the worm could then be rested in fresh sea-water for a few hours, when it was capable of lighting again.

Interesting experiments were performed with the separate elytra after they had been separated from the worm's body. Such "scales" lived and were capable of lighting for a long time. When first removed they lighted brightly and shone of their own accord for a number of minutes. They then rested dark until some stimulus caused them to illuminate again. Some lived so for sixteen hours.

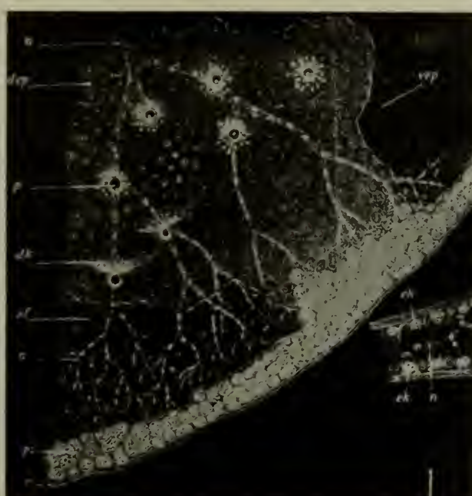
Dr. Fritz Kutschera followed up the work of Falger with more intensive studies of the conditions under which the worms in question will light, and, particularly, he tried to find out how the luciferine was secreted and whether it was consumed to produce the light in cells or in glands, or whether it was emitted from the glands and the illumination took place outside the body.

Kutschera found that the animal always lights progressively toward the tail when stimulated at any point of its body. When the stimulation is mechanical and the whole creature is shaken or moved the light may appear cephalad of the point of stimulation, but in this case the anterior light is caused by an anterior and accidental stimulation and not by a nerve impulse passing forward.

Even when cut suddenly in two parts it was only the posterior part that lighted.

It seemed impossible to demonstrate the emission of any luciferine from the surface of the lighted "scale" borders. No light could be rubbed off on the fingers or on paper or in any other way be made to show independently of the tissues. One very interesting way of treating the creature was to place it upon dry filter-paper, so that practically all water was removed from the outside of its cuticle. Under these circumstances it becomes rigid or still and stops the almost continuous movements that go on when it is

FIG. 8.



Enlarged surface view of portion of posterior half of one of above elytra. The branching nerve is shown with several light organs situated on its twigs. (After Kutschera.)

immersed or very wet. When this dry rigidity was at its height the electric current was applied and light appeared as usual. Under the magnifying glass or low power of the microscope the light was seen to come from particular points, which were most numerous on the edge of the "scale."

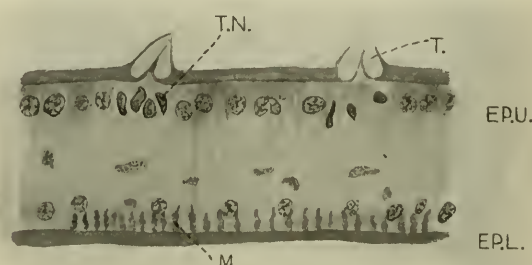
Kutschera very correctly decided that the question would best have further light thrown on it by a careful histological study of the tissues, and he made careful sections with appropriate fixation and stains for this purpose. His results may be summarized as

follows: When examined from above *in toto* the "scale" is seen to be a cellular structure whose whole upper surface is covered with a layer of large cubical epithelial cells, the outlines of which appear rounded rather than flat-sided. This indicates that some small space separates them and is filled with an extra cellular substance (Fig. 8).

It can then be seen by a little deeper focussing that a nerve rises out from the pedicel that holds the "scale" to the body, and that this nerve, after swelling into a ganglion, branches into successively finer branches that radiate in all directions through the flat scale and end in abundant points that are most abundant in the peripheral outer zone of the structure (see Figs. 7 and 8).

Where each nerve twig ends is a raised papilla, under which a

FIG. 9.



Vertical section through an anterior region of above elytrum. *t.*, "tooth" on dorsal surface; *t.n.*, nuclei of "tooth" region; *ep.u.*, upper hypodermis of elytrum; *ep.l.*, lower hypodermis. (Modified from Kutschera.)

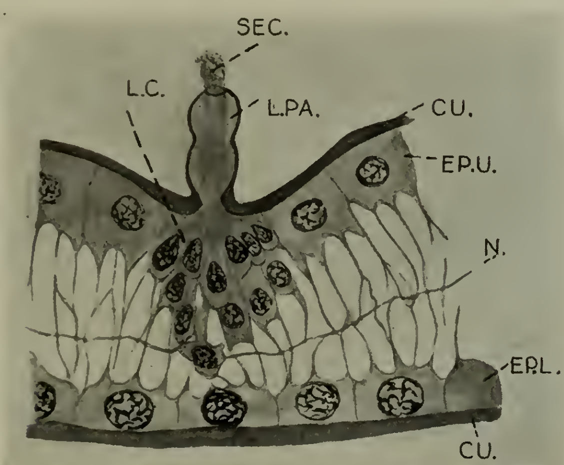
number of smaller darker nuclei are collected, indicating the presence of a number of smaller cells that lie deeper in the substance of the elytrum than the epithelial cells. Two sorts of such papilla are found. On the anterior edge of the "scale" are tooth-like projections with but few nuclei beneath them. These are mere mechanical organs of some unknown function, or, possibly, sensory organs of touch, and are not the light organs. They are comparatively fewer in number than the second form of papilla, and are shown in Fig. 9, which is a section of an anterior portion of the elytrum.

The second kind of papillæ is found mostly near the posterior edge of the scale, and have the largest number of the dark nuclei and their cells around and below them, and have proved

to be the real light organs. With the low power of the microscope they can be seen to be points of light production when the living animal is illuminating.

In the posterior edge of a vertical section of the scale taken on its antero-posterior line we can now see the structures of these light organs more plainly (Fig. 10). This section shows the scale to have an upper and a lower epithelial surface, with a loose connective-tissue mass between them (Figs. 9 and 10). As in all worms, this epithelial layer is a hypodermis and is covered with a cuticle of considerable thickness. The lower hypodermis

FIG. 10.



Vertical section through a posterior part of the same "scale" or elytrum, to show a single typical light organ. *l.c.*, light-cells; *l.pa.*, light papilla; *sec.*, secretion; *cu.*, cuticle; *ep.u.*, upper hypodermis; *ep.l.*, lower hypodermis; *n.*, region of nerve distribution. (After Kutschera)

has evenly-developed muscle-bundles in its cytoplasm (Fig. 9, *m.*), very much as the epidermis of certain cœlenterates has. No basement membrane is present, but the cells are connected with the underlying connective tissues by several branching strands of their proximal cytoplasm, as is often seen in the worms and arthropoda and but seldom in the mollusca and vertebrata (Figs. 9 and 10).

The upper epithelial cells are larger and possess larger nuclei than the lower cells just described. The cytoplasm is denser and contains a closely-packed mass of small round granules, usually

colorless, but altered to pigment granules in certain regions where the elytrum appears colored, usually black or dark brown. We can now describe the structure of two kinds of projections on the upper surface, the "teeth" and light organs in terms of these cells.

Each tooth consists (Fig. 9) of a short, modified, cone-shaped area of the cuticle, with its lumen almost opening to the outside. This cuticle of the tooth is thicker than the general cuticle and stains lighter. Immediately below it are a few modified epithelial cells that have smaller, irregular nuclei placed below the level of the hypodermis and belonging to the modified cells that form and support the structure.

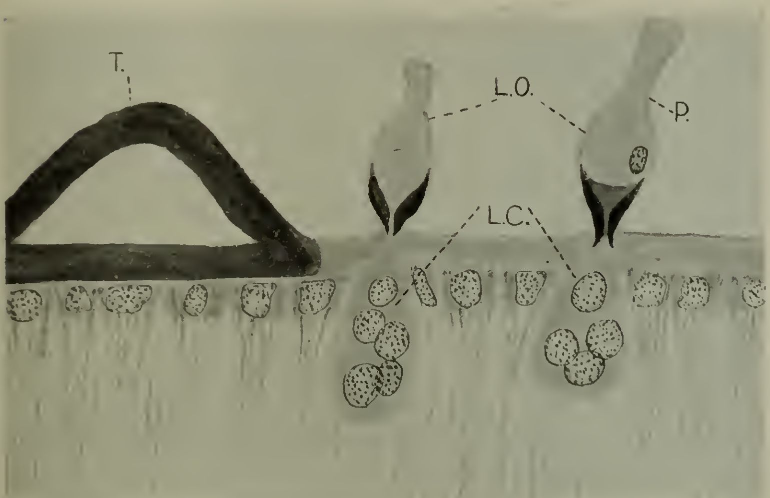
In the light organs we find somewhat similar structures (Fig. 10). Here the modified cuticle is developed from a cone into a tall papilla (*l. pa.*) with a central tubular lumen opening through its top to permit of the secretion being discharged to the exterior (*sec.*). The modified cells below it are more numerous than in the tooth and show a more glandular nature, having a darker cytoplasm and a series of lines of secretion that reach from the smaller darker nuclei up toward the tube. Their secretion is evidently of a fluid of colloid nature, and is not granular, as in so many other kinds of light-cells. This secretion fills the tube, and protrudes from its opening in many cases, as is shown in the figure (*sec.*).

From the structure of this organ we can see that there is but a small amount of secretion, and from the fact that this secretion cannot be removed from the surface of the "scale" by objects that touch it we can infer that it is burned and the light produced either in the cells, the tube, or almost instantly upon being discharged from its outer end. The tube may be used only to discharge the products of this combustion, and the enzyme or catalytic agent must be made by the same cells that make and send out the luciferine.

The writer has examined the "teeth" and light organs in the form *Lepidonotus squamata* and finds some interesting differences. The "teeth" are much larger and more highly specialized organs than in *Acholœ*, with a base and a closed top, which thus encloses a central space in the "tooth" that is hollow. Fig. 11 shows this in section. The modified epithelial cells that support the "tooth" are not prominent features, being smaller and fewer than in the unmodified hypodermis.

The light organs, while essentially the same as in *Acholæ*, are fewer but larger than in that form and, so far as the glandular portion is concerned, are more definitely organized (Fig. 11, light organ). The modified hypodermal cells that compose it have larger, heavier bodies and their cytoplasm is darker staining, owing to some granular content that is evidently luciferine and its allied products. These cells, too, are not spread about, but are gathered into a very definite mass that shows a definite oval outline (Fig.

FIG. 11.



Vertical section through a posterior portion of the elytrum of *Lepidonotus squamata*, to show one light organ (*l.o.*) and one "tooth." *l.c.*, light-cells; *l.p.*, light papilla with tube and secretion; *t.*, tooth. (Original drawing.)

11, *l. c.*). The nuclei of these light-cells also differ from the corresponding nuclei in *Acholæ* in being larger than the hypodermal nuclei. Their character shows all the indications of secretory activity, which suggests the possibility that *Lepidonotus* can shine more brightly or longer than can some of the forms already worked upon.

The connective tissue lying between the two layers of hypodermis forms a loose mesh-work with but few nuclei and with large spaces that probably contain blood, although blood-cells are hard to find in it. The nerves branch and ramify through the

middle level of this connective tissue, and careful preparations and study would undoubtedly show some definite method of blood circulation through capillaries and sinuses.

The use of this light to the animal seems quite apparent. It is used to protect the animal in the form of what may be termed a "sacrifice lure." It has already been explained how, if the worm is cut in two parts, the posterior part will light and wriggle, while the anterior part will remain dark and seek concealment. So, too,

FIG. 12.

Picture to show the method and use of lighting by a polynoid worm on Maine coast. A crab, *Cancer irroratus*, has just cut one of the worms in two with his claw. The anterior portion seeks the shelter of a stone. The posterior portion, together with detached scales, lights up and moves with wriggling movements. (Drawing by J. Bruce Horsfall from descriptions by the writer.)

will a single "scale," if detached from the body, start to shining at once. The nervous mechanism appears to act in an inhibitory manner, and, in consequence, any injury to the nerve control from the brain, by cutting or otherwise, seems to initiate the lighting process through the ganglia in the scale peduncles. Fig. 12 shows a view of this worm as it appears when lighted in the sea; also when it has been attacked by a crab that has cut it in two parts and torn off some of its "scales." The writer finds that in the waters

of Florida (Dry Tortugas), as well as in New England waters (South Harpswell, Maine, and Wood's Hole, Mass.), this worm is eagerly sought and devoured by several fishes and crustaceans. It, together with its neighbors on gravelly bottom, the luminous brittle stars, forms the chief food of the haddock on the Maine coast and its fishing banks.

THE TOMOPTERIDÆ.

This group of annelid worms are highly specialized for a pelagic life and are found, usually on the surface, in all seas. Some of the largest kinds are found in the cold waters of the boreal

FIG. 13.

Photograph of a specimen of *Tomopterus helgolandica* from the coast of Maine. (Photo by Dr. Henry B. Bigelow.)

region, while the largest number of species occur in the tropical waters of all oceans. Nearly all are exceedingly transparent in texture, like so many pelagic animals, but a few, especially some tropical forms, are decorated with a few highly-colored chromatophores which give them a brilliant but limited color pattern.

Fig. 13 shows a photograph of a large, transparent species from the waters of the gulf of Maine, and Fig. 14 represents *Tomopterus rolasi*, a colored form (color represented by black areas) from the British West Indies. Both figures show the characteristic shape of the various kinds of these worms, which is

remarkably uniform among the different species. It will be noted at once that the parapodia are highly developed as swimming organs, that are used by the animals to propel themselves rapidly on the surface of the water.

Vejdovsky was one of the first (in 1878) to note that a few symmetrically-placed, highly-pigmented, rosette-shaped organs were to be seen on some of the anterior limbs. Not all of the species possess these organs, but the majority of them do.

Von Greef, while studying the many pelagic invertebrates in the neighborhood of the island of St. Thomas, found two species,

FIG. 14.

Drawing of a specimen of *Tomopterus rolasi*. The eye-like luminous organs can be seen on the first pair of parapodia or "oars." (After von Greef.)

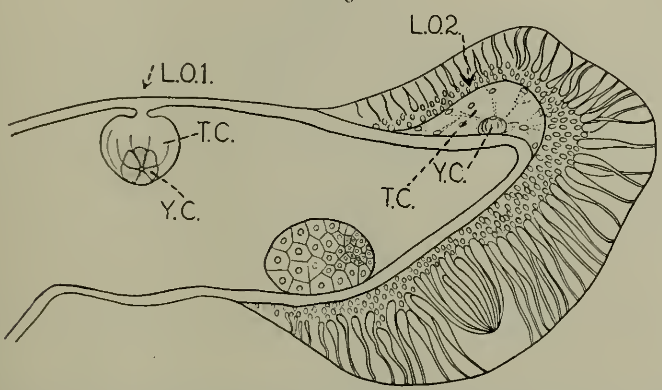
Tomopterus rolasi and *Tomopterus mariana*, in which he describes these organs more carefully and finally came to the conclusion that they were light organs. He does not state clearly just how he decided this important question: whether he actually saw the light, or whether he made the decision on account of their structure.

In the fall of 1908 Kiernik captured a species of *Tomopterus* off the coast of Norway and confirmed the conclusions of von Greef by putting them in a dark room and actually seeing the light that they gave when stimulated. He did not make a careful study, either physiological or histological, of the power, and this

worm, therefore, presents the need of, and the opportunity for, such work still to be done.

We will further examine the question by showing the partial structural work of von Greef on these organs as shown by *Tomopterus rolasi* and *Tomopterus mariana.* In both species he shows two forms of the light organ. The larger form, as shown in *Tomopterus rolasi,* consists of four large structures placed, one each, in the middle of the length of the first two pairs of oar-like appendages. In optical section (Fig. 15, *l. o.* 1) these show a central, melon-shaped mass of yellow cells (*y. c.*) placed in the proximal part of a much larger melon-shaped body of large

FIG. 15.



Drawing of an optical section of one of the first two parapodia on the body of *Tomopterus rolasi.* Partly diagrammatic. *l.o.*1, light organ on the "oar"; *l.o.*2, light organ on the "fin": *t.c.*, transparent cells; *y.c.*, yellow cells. (After von Greef.)

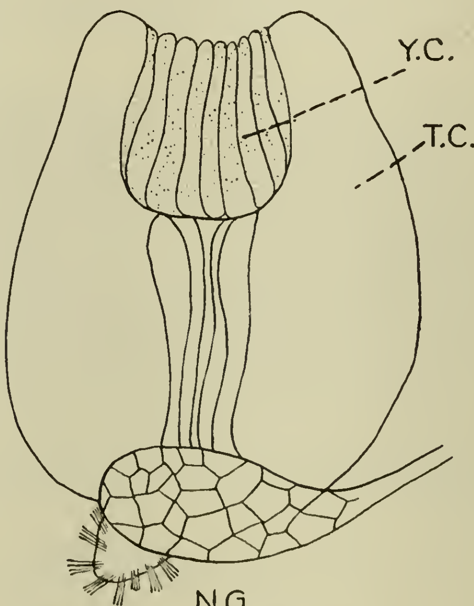
transparent cells (*t. c.*) that is sunk level with the surface of the anterior ventral edge of the integument of the " oar." The continuity of this organ with the surface epithelium is fairly well indicated in the figure, although von Greef did not have preparations that definitely showed the histological structure of the organ.

The second form of light organ is shown in the same figure (Fig. 15, *l. o.* 2), and is placed in the tissue of the "fin" that is found on the end of each " oar." Two of these fins occur on the bifurcated ends of each oar, and one of the light organs in each fin on most of the oars brings the total number of this second kind of organ up to something like twenty in all.

The same melon-shaped mass of yellow cells appears to form the principal structure in this organ as in the last (Fig. 15, *y. c.*);

and this yellow rosette is placed in a proximal position in a much larger mass of large, transparent cells, as in the last case. But the larger cells do not form as definite a melon form as in the oar organ; and a still wider modification is the way in which the whole mass of the organ is below, and covered by, the thick body epithelium and its basement membrane. No trace appears of any previous invagination, yet the writer feels certain that this entire organ is formed by an epithelial invagination in the development of the worm.

FIG. 16.



Drawing of one of the large light organs of *Tomopterus mariana*. *y.c.*, yellow cells; *t.c.*, transparent cells; *n.g.*, nerve ganglia. (After von Greef.)

An examination of one of the "oar" organs of *Tomopterus mariana* will show more concerning the origin and meaning of these organs, perhaps, than in *Tomopterus rolasi*. Here we find the same sort of elements as seen in *Tomopterus rolasi*, but the arrangement is different, more primitive (see Fig. 16). The large melon-shaped rosette of larger, transparent cells (*t. c.*) is present and is imbedded in the integument in a position that brings its distal end flush with the outer epithelium of the appendage and

shows its origin from the hypodermis. The yellow body is also present (*y. c.*) and placed in the central axis of the transparent cells, but, instead of being in a proximal position, it lies in the distal end, with the tops of the yellow cells (here stippled) level with the tops of the transparent cells and also forming, morphologically, a part of the hypodermis. This organ has also been further described by von Greef in that he has shown the presence of a ganglion (*n g.*) at its base, with a nerve coming to it and with fibres passing out of it, up between the transparent cell, to attach themselves to the bases of the yellow cells (Fig. 16, *y. c.*).

Unfortunately all of these figures and descriptions by von Greef have been made from living worms, or from very poor preparations, and no nuclei or other details of a cytological nature are given. From what we can surmise, however, it seems that the yellow cells must be the light-cells, and the transparent cells must be either a lens structure or nutrition cells connected with the organ. The whole matter presents an interesting opportunity for a careful histological and physiological study and should be worked upon with modern methods and with a sufficient supply of fresh material. It seems certain, still, that it is a true light organ.

CHÆTOPTERUS.

This remarkable and highly-specialized annelid worm is a member of the sub-order *Spioniformia,* and its species are found all over the world in tropical and temperate regions. It lives from low-water mark down to about fifteen fathoms in depth, near the shores of quiet branches of the ocean, buried in mud and sand and housed in a tough, parchment-like tube made from the secretions of its own integument. This tube is U-shaped, with the two exits projecting slightly from the ground, and the middle is considerably larger in diameter than the ends. Fig. 18 shows the shape and position of the tube.

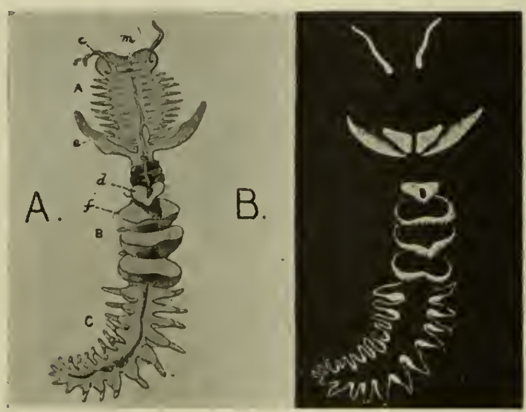
The tube is much longer and wider than the body of the worm, which can move about quite freely inside of it. The animal never leaves the tube, although at times it may reach out of it and even lie with a larger part of its body outside to get cooler and more agreeable water. Several crustaceans and worms live in the tube with it as commensals.

The worm is very soft-bodied and delicate, and in color a light yellow or flesh tint, often about the color of a tapeworm, thus

showing that it was intended for an indoor or cave life. Its eyes are small and almost useless, and it feeds on microscopic plant and animal life, which is caught by a current of water, the respiratory stream, driven by the three flat paddles in the creature's middle, and, becoming entangled in the slime on the surface of the skin, is drawn by the cilia in currents of slime to the mouth, where it is ingested.

This worm is one of the most brilliant of known luminous organisms. Fig. 17, *A,* shows it as it appears in daylight and *B* as it appears in a dark room under a moderate amount of stimulation. Here we can see that not all parts of the body light with an

FIG. 17.



Two figures of *Chætopterus variopedatus*, one in daylight to show the regions of the body; another in the dark to indicate which of these regions are light-bearing. (After Panceri.)

equal intensity, but that certain parts are more capable of luminosity than others. When a greater stimulus is applied the light becomes more widely distributed, but certain parts retain the lead in brightness. The stimulus may be chemical, electrical, or mechanical, it does not seem to matter which.

Upon studying the living, shining animal more closely and with a hand lens one notices that the light is actually given off from the body as fine clouds of luminous material that rise in the water; also, that the apparent spread of the luminous localities is not due to the operation of other glands before unlighted, but to the spread of this secretion through the water to the unlighted

parts which it masks with light. Fig. 18 shows the appearance of the worm if the observer could look at the interior of its tube from the side. The writer wishes to say that he has seen eels pull *Chætopterus* out of its tube and has often found the anterior region of their body as well as occasional whole worms in the stomach when the eel was captured and opened early in the morning, after feeding on the sand and mud flats.

The light is of the usual greenish-blue, except that, when the worm is almost exhausted or is very weakly stimulated, pale-lilac or violet flashes pass over parts of its body just before the stronger blue-green glow appears. When a lighted candle is in the dark room at the same time the light appears green.

The light comes from the skin and is evidently an external secretion of luciferine, because it comes off on the fingers if the animal is handled while lighting; also, several strong, fresh specimens glowing in a bucket of sea-water will throw out enough of the material, and it will glow long enough, to make all of the water in the vessel of a milky luminous color.

A number of workers have studied this interesting worm. Panceri wrote about it, and Dubois used it in some of his studies on animal light. Panceri described the habits of lighting and showed the regions of the integument that possessed this power to the greatest degree. In recent times Enders has studied the growth and habits of the worm and showed that the young, free swimming larva was capable of lighting, especially in the skin of the ciliated rings with which it is provided.

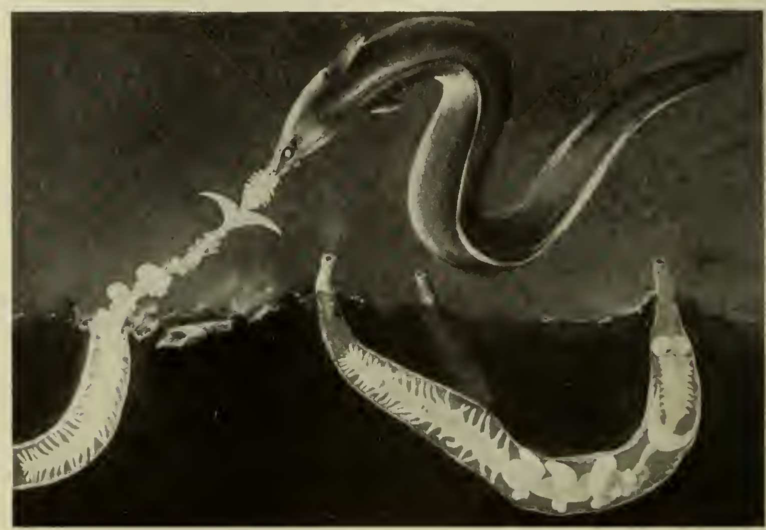
The most serious work on this power of light production has recently been done by Trojan, who did careful histologic and experimental work on the subject in a paper devoted exclusively to this phase of the organism's activities and to its tube building. The outer form of the worm is important in studying its lighting powers, and Fig. 19 shows the dorsal surface of a well-fixed and preserved specimen. The body is divided, for convenience of description, into three regions: an anterior region, a middle region, and a posterior region. We will note the locations of the lighted areas, as these are briefly described, and refer the reader also to Panceri's figure (Fig. 17) for further exposition of this point.

The anterior region is composed of some ten segments, all massed together into a body, sometimes called the "head" by the

uninitiated. The real head is small and is fused into the anterior part of this mass, its two small tentacles projecting from the mass. These tentacles are at times partly hidden by the curled edges of the large "under lip" which ends dorsally in their neighborhood. These tentacles are the seat of brilliant light when the animal is aroused, while practically none is shown on the rest of the anterior region.

The middle region is very highly specialized in form and

FIG. 18.



Drawing to show the habitat and appearance when lighting of *Chætopterus*. Eels ordinarily capture and eat a considerable number of these large worms. They usually break off and devour the anterior region, leaving the rest of the body in the tube to regenerate a new part. The tubes and ground have here been shown in imaginary section. (Drawn by J. Bruce Horsfall.)

structure. One of its first segments shows two long, wide, wing-like processes, the notopodia of the twelfth segment, which are developed from lobes of the parapodia belonging to this segment. This wing shows a triangular spot of very brilliant light on the anterior side of its base; also, its upper edge shows scattered spots of light, thick set on the extreme edge and more scattered toward the middle. The "wing" is used in "plastering" and smoothing the inside of the tube with the filament-containing secretion of certain epithelial cells.

The next portion of the middle region is almost bare of appendages, and the dorsal body wall is so thin and fits the digestive tube so closely that it appears to be absent and the dark-green gut seems to lie exposed in several bends and coils on the ventral body wall. In its midst appears one apparent remnant of the dorsal wall of the thirteenth segment, which is a knot of tissue of the same color as the usual surface of the rest of the animal. This structure is known as the accessory feeding organ (Figs. 17 and 19). It is one of the brightest spots on the worm when it is illuminated, and it is here that we must look for a good number of light-cells.

The latter part of the middle region is occupied by three large, rounded, fan-shaped paddles that represent the notopodial parts of the parapodia on the fourteenth, fifteenth, and sixteenth segments. These " fans " are breathing fans and are used to propel the respiratory and nutritive stream of sea-water that runs through the tube. Their posterior surface is illuminated when the worm is aglow. The light appears in spots, and so we will expect to find the light-cells scattered, either singly or, more probably, in groups in this region.

The rest of the worm's body, the posterior or third region, is least specialized of all and consists of a large number (from fifteen to fifty) of segments, all much alike. This is the sexual region of the animal, in whose body cavity the sperm and eggs are developed in the male and female individuals. Each segment has a well-developed lateral notopodium of large size, with a truncate base and a longer distal lobe. Each base shows, on its posterior edge, a thickened mass of epithelium which, in the dark and when the worm is stimulated, gives rise to an abundance of light. So we must also examine these regions in our search for light-cells and their accessory tissues.

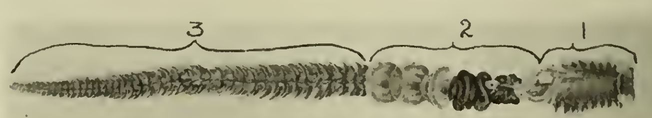
As to the creature's epithelium, it is of extraordinary development and differentiation. One of the most prominent sorts of cells is found in some thickened portion in several regions, and consists of long gland-cells filled with granules and also with fine coiled threads. These cells are secreting the material out of which the tube is built. As Trojan has shown, the threads are discharged and plastered against the inner wall of the tube with some cement substance probably derived from the granules in the same cells.

The next sort of cell is even more common, and its members are scattered very widely over the body, sometimes alone and at other

times in masses. They are very large mucous cells whose contents are not granules of mucin but large, reticulated masses of completed and dissolved mucus. Their need can be gauged by the enormous amounts of mucus that are always found on and about the worm when the tube is opened and the worm is handled. These mucous cells (Figs. 20 and 21, *m.c.*) are often mixed with the various other cells found on the body, and their function is very plainly indicated by their staining reaction as well as by the flattened and proximal position of the nucleus. In many cases they are lobed and compound cells. Their content is very soft and dilute, and in fixation they are apt to have the mucus shrunk somewhat. They also become quite hard and brittle if treated too long with the stronger alcohols.

There are now left to examine and study two other more or less common kinds of cells found in the integument of the worm

FIG. 19.



Drawing of an adult specimen of *Chætopterus*, to show its appendages and the different regions of the body. (After Enders.)

and also to decide which of these are the light-cells, or if both are.

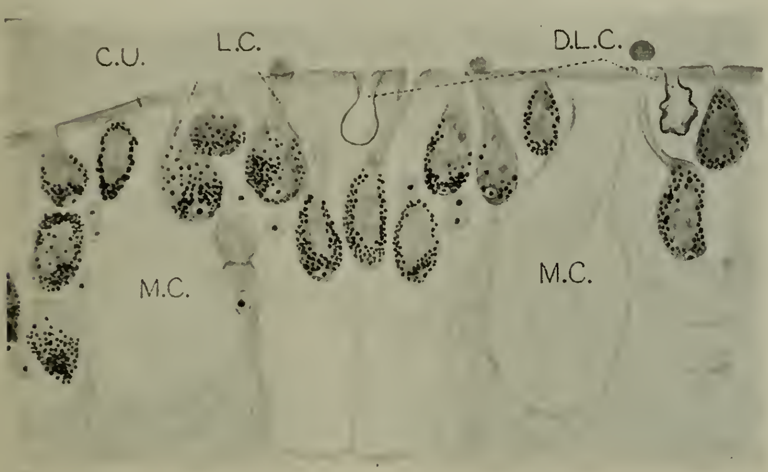
The first is a very simple cell found in large numbers on the deeper surfaces of the accessory food organ (this organ is a sucking disk and aids in no way to ingest any food), which is, we know, probably the brightest surface on the worm when lighting. These cells (Fig. 20, *l. c.*) are found imbedded in the epithelium, which is thick here and composed of mucous cells and undifferentiated hypodermal cells in about equal numbers. They are oval cells showing a dense granular cytoplasm, a distinct cell membrane, and an oval or triangular nucleus with a very heavy nuclear membrane, almost no chromatin granules, and a single large, spherical plasmosome, in which most of the chromatin seems to be situated. This nucleus lies directly against the proximal wall of the cell, usually in the middle, sometimes to one side, but always against the cell membrane.

The distal end of the cell is a duct of varying length, in any

group of cells, according to whether the cell to which it belongs is nearer or farther from the cuticle of the epithelium. If the cells are very numerous they may lie in two or more layers, and in that case those in the inner layers must have a duct that will reach between the cells of the outer layer and open through the cuticle. If, on the other hand, they are scattered and few in number, they usually all lie touching the surface with ducts of but the shortest length.

Some of the cells are emptying, and they appear to be of a

FIG. 20.



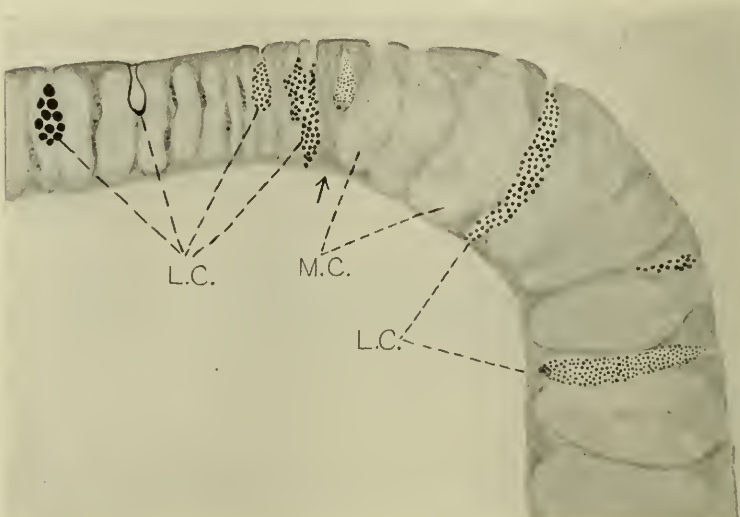
Drawing of a small portion of the epithelium from a fold of the accessory food organ on the fourteenth segment of *Chætopterus*. *cu.*, cuticle; *l.c.*, light-cells, some showing discharge of secretion; *d.l.c.*, discharged and emptied light-cells; *m.c.*, mucous cells. (Drawn from section by E. Grace White.)

secretory type that are destroyed by one cycle of secretory activity. Thus we find exhausted and empty cells near the surface in several cases (Fig. 20, *d. l. c.*). On the other hand, some of them seem to be younger and to stain darker, although it may be a renewal stage of another secretory cycle instead of the development of a new light-cell.

It seems fair to assume that these are light-cells on account of their position in this light-powerful region and also because of the absence of any other cell that appears able to perform the same function.

The second kind of cell that appears to be a light-cell is a distinctly granular one (Fig. 21, *l. c.*). It is elongate, reaching from the surface to the basement membrane of the epithelium, and is very narrow. It is most often found among the large mucous cells, and is particularly abundant on the edge of the large, fan-shaped notopodia, where we find a very bright light region when the creature is stimulated. These cells become less frequent as

FIG. 21.



Bit of epithelium from edge of one of the "fans" on the body of *Chætopterus*. Arrow marks transition from posterior edge of the narrow band to the thicker epithelium-bearing mucous cells on the posterior surface of the "fan." *l.c.*, light-cells, one of them empty; *m.c.*, mucous cells. (Drawn from section by E. Grace White.)

we pass away from this edge, which also accords with the distribution of the light.

Fig. 21 shows a drawing of a vertical section of the edge of the fan, and it can be noticed that the extreme edge is marked by a band (here seen in cross-section) of undifferentiated hypodermal cells, very long and narrow and closely packed together. On both anterior and posterior surfaces of the fan these hypodermal cells assume a glandular condition and become the large mucous cells mentioned previously. This transition is very clearly seen in Fig. 21.

Scattered among the hypodermal cells of the undifferentiated band we find a few (five to ten in each section) large, granule-secreting cells of the kind mentioned above which are undoubtedly light-cells (*l. c.*). Most of them are found on the posterior edge of the epithelial band, although some may appear near the other boundary. Further, they are also found, more sparingly distributed, among the large mucous cells on the posterior surface of the fan. Some such may be seen in the figure.

These cells all have the same kind of nucleus that the light-cells on the accessory feeding organ had, of good size, proximal, and next to the cell wall but not flattened hard against it, and with one large plasmosome, in which all of the chromatic material of the nucleus seems to be stored.

The content of such cells is a mass of granules which differ in size in the individual cells but are all of one size in each cell. This variation is quite extreme, running from very small, fine granules up to extremely large ones. In the largest-sized granules a tendency is shown toward a softening of the individual grains, and it was not long before the writer was able to see a series embracing not only all these granular cells but having as its end in one direction the first type of light-cells as described above in the accessory feeding organs; so we are dealing with only one kind of cell, after all. Whether this series means a set of stages in the ripening of the cells or not could not be decided. The writer is inclined to disbelieve this, although he is open to conviction. It seems entirely possible that light may be produced from several-sized granules of the luciferine. We know that in *Pholas* the granules are all formed at once, of the same size in the real light-cells as described by Förster. The writer has seen, however, some fine-granuled cells even in *Pholas*.

The question as to the source of the enzyme, necessary as a catalyzer in all light production through luciferine, is still to be taken up in *Chætopterus*. To be sure, we have found several other organisms in our studies so far in which this point could not be adequately solved.

One suggestion is that the mucous cells may act in this capacity. So far as we have gone it has been noticed that both structurally and in their staining capacities the cells diagnosed as luciferase units have resembled mucous cells. So it may serve as a rather weak working hypothesis that the mucous cells of this worm act

both as a mechanical mucous supply and as producers of luciferase as well.

Again, there are long, narrow gland-cells in the hypodermis that stain blue with Delafield's hæmatoxylin and that always are found in the neighborhood of the light-cells. There is a possibility that they are collapsed mucous cells which have discharged. This idea is favored by their length and thinness. But they may also be the missing element that we are in search of.

The use of the light by *Chætopterus* is a puzzle. Living as they do in a tube underground, one cannot imagine any possible use for the light. On account of the duration of the light, which it owes to the large granules that the luciferine is formed into, the luminous cloud could be given off and caused to emerge from one of the entrances of the tube. The best we can do is to surmise that it has the same use as in the case of *Pholas,* which also lives in the ground and has an enduring light also.

EARTHWORMS.

We find in biological literature so many positive statements that earthworms sometimes illuminate that the subject cannot be ignored. The scientific standing of the observers demands a careful consideration of the matter. In 1670 Grimm and in 1771 Flanguergues describe it, and in later times Moquin-Tandon, Vejdovsky, Owsiannikow, Eversmann, Duges, Giard, Moniez, Stein, Matzdorff, Molisch, and Haupt have made mention of the fact. Many of these cases are concerning common species of earthworms that we know do not ordinarily light. Since the earthworms eat vegetable matter, the most probable explanation is that the illuminating worms have been eating some luminous fungus and that the light is derived from this fungus.

(*To be continued.*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

REPORT OF THE TENTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES, MAY 25–28, 1915.

THE report is a record of the proceedings of the Conference, which is composed of state and local weights and measures officials from various parts of the United States. It contains, among other matters, short reports of the condition of weights and measures work in about twenty-five states; and technical papers dealing with the testing of electric meters, railroad track scale tests made by the Bureau of Standards, a method of adjusting railroad track scales, a discussion of automatic scales, system of keeping records, and weights and measures work from the standpoint of an efficiency engineer. The Conference adopted at this meeting extensive and comprehensive tolerances and specifications for weights and measures and weighing and measuring devices, which are given in the appendix of the report, together with a model state law on weights and measures, previously adopted.

LIFE TESTING OF INCANDESCENT LAMPS AT THE BUREAU OF STANDARDS.†

By G. W. Middlekauff, B. Mulligan, and J. F. Skogland.

[ABSTRACT.]

SINCE the year 1908 the Bureau of Standards has inspected and tested the incandescent electric lamps which have been used in all departments of the government, amounting at present to about 1,250,000 lamps annually. The specifications under which these lamps are purchased are published by the Bureau as Circular 13 and are recognized as standard by the manufacturers as well as by the government. They are used also by many other purchasers of lamps.

Application of these specifications necessitates careful inspection and reliable life tests. The lamps are first inspected at the factory by Bureau inspectors, five per cent. taken at random from

* Communicated by the Director.

† Scientific Paper No. 265.

each package being examined. These must conform to certain specified requirements as regards bulbs, bases, filaments, vacuum, etc. Lamps which pass these requirements are then run on the photometer to determine their candle-power and the watts consumed, and if the required percentage of the lamps falls within the specified limits the lamp nearest the mean value of each group of not more than 250 lamps is selected, labelled, and sent to the Bureau to represent the group on life test.

Upon their receipt at the Bureau these samples, which at present amount to about 5000 annually, are measured for voltage corresponding to the efficiency at which it is desired to run them on life test. A life test is said to be *normal* when it is run at the efficiency required by the specifications, and *forced* when it is run at a higher efficiency. Carbon lamps are usually tested at normal, while tungsten lamps, on account of their long life at normal, are forced in order to complete the test without unreasonably delaying the delivery of the lamps they represent, which must be held by the manufacturers pending the results of the test. The life is specified as the number of hours a lamp at rated efficiency will burn until its candle-power has become reduced to 80 per cent. of its original value. In the case of forced tests the actual life must be corrected by the proper factors to correspond to normal (rated) efficiency.

In order to facilitate the photometric measurements of the life-test lamps and still secure a permanent, accurate, and, as nearly as possible, automatic card record of each lamp tested, certain modifications and additions have been made to the photometer used in this work. These include a watts-per-candle computer and a recording device by which observed values of candle-power, watts, watts per candle, and actual life are recorded on a separate card for each lamp. These records are made in such a way that life at forced efficiency may be corrected to life at normal without computation or reference to tables of factors.

The test lamps, having been rated as described above, are then ready for the life racks, where they are burned at the respective voltages found until their candle-power has dropped 20 per cent. In order to obtain reliable results the voltage must be accurately adjusted and carefully regulated during the test. The Bureau's life-test electrical equipment is so designed that by a system of auto-transformation any voltage from 78 to 260 may be obtained

and the exact value approximated to within one-tenth of one per cent. By a Tirrill regulator this voltage is kept within the specified limits of plus or minus a quarter of one per cent.

Another important element in a life test is the elapsed time of burning. This is accurately determined by means of an electric clock placed in the master-clock circuit of the Bureau. It is so arranged that the clock is short-circuited when current is not being supplied to the racks.

REGULATION OF ELECTROTYPING SOLUTIONS.*

[ABSTRACT.]

The second edition of this circular, which has been entirely rewritten, is devoted principally to a discussion of the effect of various factors upon the deposition of copper in electrotyping baths, based upon the literature on this subject, and upon recent investigations by the Bureau of Standards. The limits of composition of solutions, temperature, and current density are defined, within which copper having the required tensile strength and ductility may be obtained. The circular also includes conversion tables for Fahrenheit and Centigrade temperatures, metric and customary units, and specific gravity and degrees Baumé. Definitions of important electrical terms are given, and also tables showing the weight and thickness of copper deposited by a given current in a specified time.

PROTECTED THERMO-ELEMENTS.†

By Arthur W. Gray.

The paper describes a convenient mounting for protecting laboratory thermo-elements from damage by contamination or by mechanical strains.

The closed tube which covers the temperature determining end of the thermo-element has its open end cemented into one end of a flexible copper tube, through which the wires, properly insulated, pass to a head at the other end. Projecting downwards from this head is a glass tube which contains the ice junction. The head is provided with neutral binding posts for receiving the leads to the apparatus employed for measuring the electromo-

* Circular 52. Second edition.

† Scientific Paper No. 276.

tive force by which the temperature is determined, and contains phosphorus pentoxide to prevent moisture films from being deposited within the protective covering.

The ice-bath is contained in a vacuum jar which is protected by a metal case. By means of a bayonet joint this is suspended from the cover, which is fastened to a rod fitting the standard laboratory clamps. The head of the thermo-element telescopes with moderate friction into a split tube which projects upward from the top of the ice-bottle cover. When it becomes necessary to renew the ice, a slight turn of the case containing the vacuum jar frees the bayonet joint and permits lowering of the ice-bath without disturbing anything else.

Application of X-rays to Metallurgy. Anon. (*Metallurgical and Chemical Engineering,* vol. xiv, No. 6, March 15, 1916.)—About one year ago it had been proved that, with the proper X-ray equipment and correct time of exposure, blowholes and similar defects could be disclosed in solid metal of considerable thickness. Since that time the special equipment required for that kind of work has been further developed, and several factors essential to systematic and successful routine work have been established: proportion of required time of exposure to thickness of metal; dimension of smallest air inclusion that could be detected in a given thickness of metal; regulation of electric current to obtain maximum efficiency and the best results. Other points which had to be considered were to find the direction from which further progress in the application of X-rays to metallurgical work could be expected, and to establish the technic of metallography.

By ardent research work carried on in this country's finest laboratories, these problems were completely solved. The method has already been successfully applied to research work in connection with important metallurgical problems; for instance, that of casting copper. If copper is cast without additions, the metal is full of pores and blowholes, mechanically unfit, and of low electrical conductivity. The use of boron flax has remedied the difficulty of obtaining sound copper castings of high conductivity. In the difficult research problems of this work, X-ray investigations were applied with much success; stereoscopic radio-photographs of copper castings were taken, so that not only the size but also the relative depths of the pores could be studied. Without the use of X-rays it would have been necessary to machine off layer after layer of the many sample castings. Even then the experimenter would have had to build up a mental picture of the defects in his casting on the basis of what he had seen on each of the exposed layers. From the radiographs it was possible to see all these defects at once without destroying the castings.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A PRECISION SHUTTER TESTING INSTRUMENT.†

By P. G. Nutting.

A PRECISION instrument for testing photographic shutters should provide means of determining the rate of opening and closing of a shutter as well as the time it is open. By merely projecting an image of the shutter upon a drum or disk having a photographic surface and rotating at a known speed, the time of opening may be readily determined. This method is in common use in many shutter factories.

For precision testing it is only necessary to interrupt the beam of light by which the shutter opening is photographed. These interruptions should be of a high and constant known frequency, and the duration of each flash should be very much shorter than the interval between flashes in order to obtain sharp images of the shutter opening. The literature of photography is full of descriptions of apparatus satisfying the above conditions to a greater or less degree. The testing instruments of Abney and of Campbell and Smith, of the National Physical Laboratory, are by far the best of those described, but each of these was open to objections so serious that the design of a new type for apparatus was considered advisable. In this the interruptions are at the rate of 1000 per second to within a maximum error of less than one-half per cent., the duration of an exposure is but 1/30,000 second, while the whole instrument is simple and inexpensive and easy to operate.

In the apparatus described the illuminating beam is reflected from a crown of 20 plane mirrors rotating at 50 revolutions a second. A small projection lantern supplies the light used, the condenser of the lantern focussing an image of the arc crater at the mirror surface. The reflected beam falls on a simple lens behind which the shutter to be tested is held in a universal iris

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* Communicated by the Director.

† Communication No. 37 from the Research Laboratory of the Eastman Kodak Company.

holder. An image of the shutter is formed by a small camera lens (90 mm. E. F. L.) on a band of cinematograph film (negative) attached to the rim of an aluminum wheel 12 inches in diameter. This wheel, just before the shutter is snapped, is set in rapid rotation by means of a crank and gearing. It is enclosed in a light-tight box, so that wheel and box are readily lifted from the machine and taken to a dark room for loading and development.

The crown of mirrors is rotated at a very constant speed by means of a Leeds-Northrup governed motor making 1200 revolutions per minute. For determining speed, the shaft of the mirror crown carries a worm, and a single gear is arranged to be easily thrown into mesh with this. The revolutions of the gear wheel are counted with a stop-watch.

The duration of each flash is determined by the angular width of light beam at the lantern condenser. The beam at this point is limited by a vertical slit 2 mm. wide. The width of the beam as it flashes by the shutter opening is about one-thirtieth the distance between flashes, hence each exposure is about 1/30,000 second. Sharp shutter images were obtained even with film speeds so high as to give completely separated images of shutters fully open.

The three feet of film can take only about 50 shutter images without serious overlapping. To record shutter speeds of 1/10, 1/5, 1/2, and 1 second, the image is restricted to a narrow band by inserting a 1 mm. slit close in front of the moving film. To save counting the hundreds of images obtained at slower shutter speeds, one of the twenty rotating mirrors was painted black, thus rendering the shutter images in blocks of twenty.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

CANDLE-POWER MEASUREMENTS OF SERIES GAS-FILLED INCANDESCENT LAMPS.

By Ralph C. Robinson.†

This paper is an extension of one presented before the Illuminating Engineering Society (*Transactions of the Illuminating Engineering Society*, 11, 187–91, March 20, 1916).

The customary rating of incandescent lamps in mean horizontal candle-power is not satisfactory for gas-filled lamps, and is being changed to spherical candle-power, or lumens. The simplest way of doing this is to measure the mean horizontal candle-power and multiply by a suitable reduction factor. Small variations in the form of the filament, however, render this method inaccurate. Measurements have been made to show the variation in reduction factor for different filament positions. Four filaments of the customary spiral form, and having as nearly as possible the same spacing, diameter, leeds, and number of turns, were mounted in different positions—vertical, horizontal, diagonal, and V-shaped—and were run at the same average temperature of 2825° K. The mean horizontal candle-power was determined by taking measurements about the stationary lamp at intervals of 10°. Curves showing the candle-power distribution are given. The reduction factors obtained for the four filaments were 0.74, 1.01, 0.78, and 0.82 respectively, showing the very marked effect of variation in filament form. It is concluded that gas-filled lamps should be rated in terms of watts per spherical candle-power, as the variation in this value with change of form is very small.

The method of measuring the filament temperature by color match, and of photometering with the standard lamp running at low temperatures compensated by blue-glass screens, is outlined.

* Communicated by the Director.

† *General Electric Review*, 19, 323–6, April, 1916.

THE HOT CATHODE ARGON GAS-FILLED RECTIFIER.

By G. Stanley Meikle.*

CONDITIONS existing in a discharge tube equipped with a hot cathode in the presence of different pressures of gas have been investigated with reference to practical use as a rectifier. The high vacuum kenotron supplies currents up to 250 milliampères on 100,000 volts, but its drop of 100 to 500 volts prevents its use on low-voltage circuits. Introduction of positive ions neutralizes the space charge and so lowers the voltage required. But even traces of certain gases cut the electron emission to a small fraction. Moreover, the positive ion velocity then becomes so great that the cathode is rapidly disintegrated by bombardment. By proper adjustment of the pressure of a selected gas it has proved possible to practically eliminate disintegration, and produce a rectifier capable of handling currents from a few milliampères to high values at voltages ranging up to several thousand. Details of construction and cuts of several such rectifiers are given.

Certain impurities even in traces are very injurious, and substances are introduced which react chemically and so keep the gas pure.

Work in argon indicates that rectification is possible at all pressures. Increase of pressure raises the starting voltage and the cathode temperature required, but the voltage for operation is increased only slowly. At pressures between 3 and 8 cm. the disintegration of the cathode is at a minimum and the starting voltage is low.

The construction and connections of half-and full-wave rectifiers and of the self-starting device are discussed. The efficiency of the tube increases as the supply voltage rises. The arc drop with externally excited filament is from 4 to 8 volts, and the energy consumed in keeping the filament cathode hot is less than 40 watts. This makes the total energy consumed by a 6-ampère tube equivalent to that of a rectifier having an arc drop of from 10.66 to 14.66 volts.

The tubes operate satisfactorily on currents varying over a wide range, and can be started as low as 20 volts and maintained on 14 volts. The life of the low-current, low-voltage type varies from 900 to 3000 hours, and of the higher voltage from 500 to

* *General Electric Review*, 19, 297–304, April, 1916.

1000 hours. Many of the former have been in actual service for over 18 months. Oscillograms of the rectifying arc are given, showing, in all cases, perfect rectification.

THE PRODUCTION OF CONSTANT HIGH POTENTIAL WITH MODERATE POWER CAPACITY.

By A. W. Hull.*

THIS paper gives in much greater detail the material described under the title "A Powerful Source of Constant High Potential" (*Physical Review,* 7, 405–7, March, 1916).

A source of power, furnishing from 1 to 50 kilowatts at voltages between 10,000 and 200,000, and 5 kilowatts between 10,000 and 100,000 volts, with a voltage fluctuation in the latter case of less than 1 per cent., is described. The method avoids the use of electrostatic machines or low-voltage, direct-current generators in series, the only previous methods for producing constant high potential, with their inherent disadvantages, and rectifies high-tension alternating current by means of kenotrons. The direct current obtained is fed to a high-voltage condenser of sufficient capacity to supply the desired current during that part of each cycle when it is receiving none, with a voltage drop not exceeding a certain small amount. If a condenser of smaller capacity be used the fluctuations may be damped down by the use of another condenser and a choking coil.

The apparatus designed and used for over eight months in connection with investigations on X-ray spectra is described in detail, taking up in turn the generator, transformer, kenotron, condensers, inductance, voltmeter resistance, and the function of each, with discussion of the theory, and illustrative oscillograms. The fact that even in its present crude form the apparatus operates extremely well is a strong recommendation of the method. By use of a three-phase, 2000-cycle current and six kenotrons it would be possible with the present apparatus to furnish 100 kilowatts at 100 KV with the same constancy, and there is every reason to expect that this can be increased to 1000 kilowatts in the near future.

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* *General Electric Review,* 19, 173–81, March, 1916.

THE CHARACTERISTICS OF TUNGSTEN FILAMENTS AS FUNCTIONS OF TEMPERATURE.

By Irving Langmuir.*

SIMILAR material is given in each of the above references, but the second presents it in a more concise and convenient form, and omits most of the detailed discussion.

Any property of a filament which varies with the temperature may be used, after proper calibration, as a means of estimating the filament temperature.

Eighteen such properties are grouped, according to the knowledge of dimensions required for their use, under the headings:

1. Requiring no dimensions.
2. Requiring both length and diameter.
3. Requiring diameter only.
4. Requiring length only.

The method of application, mathematical relations, and advantages of each are discussed. A detailed study of the characteristics of tungsten filaments as functions of dimensions and temperature has been made, and the data obtained and those obtained by other investigators are discussed and compared. Experimental details are given and the results are collected and recomputed in tables giving:

1. Volt-ampère-candle-power characteristics and derived functions of tungsten filaments from 273 to 3540° K., corrected for cooling effect of leeds.

2. Specific resistance of tungsten from 300 to 3540° K.

3. Total emissivity of tungsten compared with the black body as a unit up to 3540° K.

4. Intrinsic brilliancy of black body as a function of the temperature in terms of the mechanical equivalent of light. Mechanical equivalent of 0.00121 watt per lumen found.

5. Brilliancy of black body from 1300 to 3500° K., comparing results of various investigators.

6. Emissivity of tungsten as function of wave-length and temperature from color of emitted light.

A formula for the approximate linear thermal expansion of tungsten between 1200 and 2500° K. is given.

* *Physical Review*, 7, 302–33, March, 1916; *General Electric Review*, 19, 208–12, March, 1916.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 19, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 8.

Mr. Charles E. Bonine, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The paper of the evening was presented by George R. Olshausen, Ph.D., of the Bureau of Standards, Washington, D. C., and was entitled "The Testing of Engineering Materials." The work done by the Bureau of Standards in coöperation with other organizations was described and detailed information was given of the elaborate series of tests on the strength of columns which were conducted at the Bureau. The apparatus used in these tests and the various types of columns tested were fully described and the results given in detail.

Experiments and investigations made with other materials, such as glass, steel rails, and bolts, were outlined.

After a discussion by Professors Marburg, Lanza, and others the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR.

1915–1916.

COURSES OF INSTRUCTION.

The ninety-second year of The Franklin Institute School of Mechanic Arts closed April 6, 1916. During the year classes were formed in Mechanical Drawing, Architectural Drawing and Design, Freehand Drawing and Water Color, Mensuration and Algebra, Plane Geometry and Trigonometry, Applied Mechanics, Strength of Materials and Structural Design, Steam Generation, and Theoretical and Practical Naval Architecture. A special class in Algebra was also formed during the second year.

REGISTRATION.

Large classes were enrolled in first year Mechanical Drawing, first year Mathematics, Naval Architecture and the special course in Algebra. The total registration in all Departments was three hundred and seven, an increase of about 15 per cent. over that of last year.

ATTENDANCE AND PROGRESS.

The high grade of work done by the students and their regular attendance indicate that the School has completed a satisfactory year. During the first term forty-six students made an average of 90 per cent., or over, and forty-two had a perfect attendance record. During the second term forty-two students made an average of 90 per cent., or over, and twenty-seven had a perfect attendance.

FACULTY.

Mr. Edgar P. Trask, of Wm. Cramp & Sons, was appointed to fill the vacancy caused by the resignation of Mr. H. C. Towle, former instructor in Naval Architecture, and Mr. B. A. Owen was appointed to continue the work of Mr. Elmer Bark in Mechanics. Mr. Wm. E. Bullock, who had been Assistant Director for four years, accepted a position in New York, and Mr. Simeon van T. Jester was made Assistant Director, at the same time continuing his work in Mathematics. No other changes were made in the Faculty, all other instructors meeting their classes as in previous years.

SCHOLARSHIPS.

Twenty-seven scholarships were available for students of the School; six of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; sixteen scholarships were derived from the Isaac B. Thorn Fund and were awarded to students in Mathematics and Mechanics; the remaining five scholarships were offered by Hon. G. W. Edmonds.

PRIZES.

Valuable prizes were offered by Mr. Samuel M. Vauclain, Vice-President of The Baldwin Locomotive Works; by Mr. J. B. McCall, President of the Philadelphia Electric Company, and by Mr. Wilfred Lewis, President of The Tabor Manufacturing Company. Mr. Vauclain's prize is to be awarded to the student having the best record in the Department of Mechanics, Mr. McCall's prize to the student having the best record in the Department of Mathematics, and Mr. Lewis' prize to a meritorious student in the Department of Mechanics.

The Alumni Association continued its special prizes to the students having the best records and to students having a perfect attendance for the year.

VISITS.

Nine visits to places of engineering interest were paid on Saturday afternoons during the season, as follows: J. G. Brill Company, Milbourne Mills, Otto Gas Engine Works, The Curtis Publishing Company, Philadelphia Rapid Transit Company's Beach Power House, Philadelphia Electric Company's Station "J" at Tacony, Link-Belt Company, University of Pennsylvania, and Queen Lane Pumping Station.

HONORS.

Certificates for the satisfactory completion of a two-year course in one of the three Departments of Drawing, Mathematics and Mechanics are this year awarded to thirty-six students. The names of graduates for the season 1915–1916 are appended, as also are the names of those students to whom are awarded the scholarships and prizes indicated above, and of those granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

I desire to express my appreciation of the very efficient work done by the members of the Faculty and the hearty coöperation of the Committee on Instruction.

Respectfully submitted,

WM. H. THORNE,
Director.

April 14, 1916.

LIST OF GRADUATES, ETC., 1915-16.

CERTIFICATES.

CERTIFICATES ON THE SATISFACTORY COMPLETION OF FULL COURSES ARE AWARDED AS FOLLOWS:

MECHANICAL DRAWING.

Ellis Mortan Ayars
Howard A. Craig
Edward S. DeHart
Arthur H. Eilitz
Joseph Green
Andrew Hetherington
Robert Kauch
Bernard Lange
Alvin J. Lynch
Arthur J. Mannix
Charles Markert
Thomas Murtaugh
David Pascal
Abraham Rosenberg
Reuben Schmerling
George W. Williams, Jr.

ARCHITECTURAL DRAWING.

William Gronewald, Jr.
Clarence H. Jaggers
Joseph Matchett
John M. McAveney
Arthur J. Schwab, Jr.

FREEHAND DRAWING AND WATER COLOR.

George Frederick Smith

MATHEMATICS.

Daniel Batezel
Charles J. Culin
Raymond J. Davis
Fred Grube
Elwood L. Kieme
Myer Kratchman
J. P. Lyons
Raymond Mattis
William Münch
Arthur Rappaport
Otto P. Schuman

MECHANICS.

E. Victor Cooley
John L. Starr
John J. Stevenson

EDMONDS SCHOLARSHIPS.

Winter and Spring Terms.

George L Dreeman,
Mathematics
Harry Haering,
Mathematics
Joseph Ritchie,
Mathematics
George W. Williams, Jr.
Drawing

BARTOL SCHOLARSHIPS.

Department of Drawing.

WINTER TERM.

E. Barrie Powers,
Mechanical

SPRING TERM.

William Callingham,
Mechanical
Harry E. Chaney,
Mechanical
Leon Chatelaine,
Architectural
Christian P. Kopp,
Freehand
Henry J. Schmid,
Mechanical

THORN SCHOLARSHIPS.

WINTER TERM.

Clarence E. Baittinger,
Mechanics
Daniel Batezel,
Mathematics
Joseph Hecking, Jr.,
Mathematics
Arthur Rappaport,
Mathematics
William C. Schmoll,
Mathematics
E. Victor Cooley,
Mechanics
W. Gordon Cowan,
Mathematics
Charles J. Culin,
Mathematics
Otto P. Schuman,
Mathematics
John L. Starr,
Mechanics

SPRING TERM.

Clarence E. Baittinger,
Mechanics
Fred Grube,
Mathematics
Joseph Hecking, Jr.,
Mathematics
William T. Owens,
Mathematics
Arthur Rappaport,
Mathematics

MR. S. M. VAUCLAIN'S PRIZE.

MECHANICS.

E. Victory Cooley

MR. WILFRED LEWIS' PRIZE.

MECHANICS.

Albert Wm. Drobile

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

Charles J. Culin

NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Albert L. Charbonnier

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE'S PRIZES.

AWARDED TO GRADUATES.

E. Victor Cooley,
Mechanics
Thomas I. Cooper,
Naval Architecture
Charles J. Culin,
Mathematics
Christian P. Kopp,
Freehand Drawing
Everett Barrie Powers,
Architectural Drawing
George W. Williams, Jr.,
Mechanical Drawing

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 5, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 5, 1916.

MR. C. E. BONINE *in the Chair.*

The following reports were presented for first reading:

No. 2657.—Paint and Varnish Remover.

No. 2667.—Dixie Magneto.

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1915:

No. 2662.—The Howard N. Potts Medal to Mr. W. S. Murray, of Hartford, Conn., for his paper entitled "Conditions Affecting the Success of Main Line Electrification," described by the sub-committee as an original and highly valuable contribution to an important phase of the transportation problem.

No. 2663.—The Edward Longstreth Medal of Merit to Mr. G. W. Fuller, of New York City, N. Y., for his paper entitled "Biochemical and Engineering Aspects of Sanitary Water Supply," described by the sub-committee as a comprehensive description of practical means of measuring the sanitary qualities of public water supplies.

No. 2664.—The Edward Longstreth Medal of Merit to Mr. Robert R. Abbott, of Cleveland, Ohio, for his paper entitled "Modern Steels and Their Heat Treatment," described by the sub-committee as a comprehensive statement of the best practice in the heat treatment of modern steels.

No. 2665.—The Edward Longstreth Medal of Merit to Major A. S. Eve, of Montreal, Canada, for his paper entitled "Modern Views on the Constitution of the Atom," described by the sub-committee as a lucid and comprehensive discussion of modern views on the constitution of the atom.

No. 2666.—The Edward Longstreth Medal of Merit to Dr. George F. Stradling, of Philadelphia, Pa., for his paper entitled "Modern Theories of Magnetism," described by the sub-committee as a comprehensive account of the modern theories of the phenomena of magnetism.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, March 23, 1916, at 8 o'clock P.M.

Mr. Charles Penrose and Mr. Joseph H. Tracey presided jointly.

Dr. Harold Pender, Professor of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa., delivered a lecture, entitled "Recent Developments in Electrical Apparatus." This lecture dealt with the operating characteristics of the more important types of electrical apparatus lately developed in connection with the distribution and utilization of electric power. New types of transmission line equipment and accessories were described, as well as the latest forms of traction motors, phase converters, rectifiers, etc.

After the lecture Clarence E. Clewell, Assistant Professor of Electrical Engineering, University of Pennsylvania, gave a brief account of the progress in electric lighting and the development of the gas-filled lamp, which was followed by an interesting discussion of the lecture.

A rising vote of thanks was extended to Dr. Pender, and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 30, 1916, at 8 o'clock P.M.

Prof. A. E. Outerbridge, Jr., occupied the chair.

The paper on "Some Problems in Physical Metallurgy at the Bureau of Standards," by George K. Burgess, Sc.D., Chief, Division of Metallurgy, Bureau of Standards, Washington, D. C., announced for this evening, was, due to Dr. Burgess's indisposition, presented by his associate, Dr. Paul D. Merica.

The lecture was fully illustrated with lantern slides and included references to the production of sound ingots and steel, failures of structural bronze, fusible boiler plugs, and the coöperative work of the Bureau of Standards with the American Institute of Metals on specifications for brasses and bronzes. The status of the investigation of railway materials at the Bureau was also described.

After an interesting discussion by Prof. E. Marburg, Professor Outerbridge, Mr. G. H. Clamer, and others, a vote of thanks was extended to the speaker and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, April 6, 1916, at 8 o'clock P.M.

Prof. A. E. Outerbridge, Jr., occupied the chair.

Professor Outerbridge introduced Mr. Charles J. Gadd, Chief Engineer, American Iron and Steel Company, Lebanon, Pa., who presented a paper, entitled "Use of Powdered Coal in Metallurgical Processes." Mr. Gadd outlined briefly, with the help of lantern slides, the method of drying, conveying, and applying pulverized coal to metallurgical furnaces, and referred especially to the results obtained by the use of such coal in puddling, heating, and open-hearth furnaces with waste-heat boilers.

After an interesting discussion a vote of thanks was extended to the speaker and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, April 12, 1916.*)

RESIDENT.

MR. LEONARD W. COLEMAN, superintendent, The Carson College for Orphan Girls, and for mail, 211 Lansdowne Avenue, Wayne, Pa.

MR. SAMUEL M. CURWEN, president, The J. G. Brill Company, Philadelphia, Pa., and for mail, Haverford, Pa.

MR. G. L. KOTHNY, consulting engineer, C. H. Wheeler Manufacturing Company, Eighteenth Street and Lehigh Avenue, Philadelphia, Pa.

MR. ROBERT SUCZEK, mechanical engineer, C. H. Wheeler Manufacturing Company, Eighteenth Street and Lehigh Avenue, Philadelphia, Pa.
MR. JAMES G. VAIL, chief chemist, Philadelphia Quartz Company, Chester, Pa.

NON-RESIDENT.

MR. CARL E. AKELEY, taxidermist and sculptor, American Museum of Natural History, 77th Street and Central Park West, New York City, N. Y.
MR. ALFRED E. WALLER, electrical engineer, 184 Archer Avenue, Mt. Vernon, N. Y.

ASSOCIATE.

MR. ARTHUR SYNNESTVEDT, student-at-law, 1201 Chestnut Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. C. G. BUCHANAN, 16 North Ninth Street, Newark, N. J.
MR. W. W. DAVIS, care By-Products Coke Corporation, McCormick Building, Chicago, Ill.
MR. JOHN P. EATON, 2642 North Napa Street, Philadelphia, Pa.
MR. E. HEITMANN, Belleview Terrace, St. Catharines, Ontario.
DR. CARL HERING, 210 South Thirteenth Street, Philadelphia, Pa.
MR. HENRY M. KOLB, 809 Widener Building, Philadelphia, Pa.
MR. P. M. LINCOLN, Railway and Lighting Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
MR. ROBERT RIDGWAY, care Public Service Commission, 120 Broadway, New York City, N. Y.
MR. GEORGE VON UTASSY, 449 Fourth Avenue, New York City, N. Y.
MR. F. R. WADLEIGH, 1110 Land Title Building, Philadelphia, Pa.
MR. G. A. WELLS, Fairoaks Farm, Darien, Conn.
MR. F. W. WESTON, 120 Broadway, New York City, N. Y.
MR. ARTHUR M. WILSON, 706 Stock Exchange Building, Philadelphia, Pa.

NECROLOGY.

JOHN McILHENNY.

1830–1916.

John McIlhenny, an early pioneer in the field of gas engineering, born in Philadelphia on April 22, 1830, passed away at his home in the Germantown suburb of this city on February 23.

His public school education was supplemented by a course in the night schools of The Franklin Institute and by an apprenticeship in the machine shop of the Southwark Foundry. About 1856, after a short experience in the Philadelphia Gas Works, under direction of that earlier master gas engineer, John C. Cresson, he superintended the building of the gas works in Wilmington, N. C., for the contractors, Perdicaris & Hoy, and for some years after the com-

pletion of that work he was engaged in similar undertakings for the same firm in various cities of the South. The beginning of the Civil War found him building the gas plant in Columbus, Ga., and there he made his home during the following twenty years. The last battle of the Civil War was marked by the burning of Columbus, leaving many of its people in a state of great destitution. In the reconstruction period which followed Mr. McIlhenny, together with his young wife, took a leading part in bringing order out of the prevailing economic and social chaos. He was several times elected Mayor of Columbus, and in that capacity started various municipal reforms, giving particular attention to the organization, in 1866, of a system of public schools, until then entirely wanting in that community. In this organization special provision was made for the children orphaned by the war, many of whom were growing up in idleness and ignorance, a menace to their own and the general welfare. The funds for this purpose were obtained by Mr. McIlhenny through special collections, to which he was always a leading contributor. The new system included schools for the colored children, and when, subsequently, the colored schools established by the Freedmen's Bureau were to be discontinued they were incorporated with the municipal system and continued by its Board of Trustees.

Various other new enterprises were started in Columbus by Mr. McIlhenny, including a cotton mill of his own, in which he instituted the ten-hour day when all other mills were working twelve.

He also led the way in the Sunday closing of saloons, and had the satisfaction of seeing his example followed in other cities of the state. One of the most notable results of Mr. McIlhenny's activity in Columbus was his early introduction of a high-pressure water service on its main streets to provide better fire protection than was being afforded by the existing system of cisterns and inadequate fire engines. He arranged for the use of a large pump, operated by water power at a cotton mill, and superintended the laying of the pipes, the cost to the city being scarcely more than that of the pipe itself. It brought about a great reduction in insurance rates in the district covered, and its value in that respect, as also its efficiency, attracted general attention. Various insurance companies sent representatives to Columbus to investigate the system, which thus became the precursor of the systems later developed in other cities for the same purpose.

Coming back to Philadelphia in 1877, Mr. McIlhenny, in addition to his business and professional activities, continued his interest in civic and communal affairs. He was one of the founders of the Pennsylvania Scotch-Irish Society and also of the National Society of that name, availing himself of the latter organization to promote the growing spirit of renewed harmony between the North and the South.

The death of his wife occurred but a little over a year before his own, two sons and three daughters surviving him.

Mr. T. Wistar Brown, 235 Chestnut Street, Philadelphia, Pa.
Mr. Henry A. Rogers, 4007 Powelton Avenue, Philadelphia, Pa.
Mr. Dillwyn Wistar, 970 Drexel Building, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

American Electrochemical Society.—Transactions, vol. 28. 1915.
Association of Municipal and Sanitary Engineers and Surveyors.—Proceedings, vols. 1 to 38. 1873 to 1912.
Hool, George A.—Reinforced Concrete Construction. 3 volumes. 1912–1916.
Ibbotson, F., and Aitchison, L.—Analysis of Non-ferrous Alloys. 1915.
Jahrbuch für das Eisenhüttenwesen.—Jahrgang, No. 5. 1904.
Luckiesh, M.—Color and Its Applications. 1915.
National Association of Railroad Commissioners.—Proceedings, vol. 26. 1914.
Nernst, Walther.—Theory of the Solid State. 1914.
Newell, Fred. H.—Irrigation Management. 1916.
Northeast Coast Institution of Engineers and Shipbuilders.—Transactions, vols. 1 to 26. 1884 to 1910.
Ostwald, Wolfgang.—Handbook of Colloid Chemistry. 1915.
Photograms for 1915.
Rivington's Notes on Building Construction.—Edited by W. N. Twelvetrees. 2 volumes. 1915.
Surveyor's Institution.—Professional Notes, vols. 1 to 13. 1886 to 1906.
Surveyor's Institution.—Transactions, vols. 1 to 37. 1868 to 1905.
Willows, R. S., and Hatschek, E.—Surface Tension and Surface Energy. 1915.
Worden, Edw. C.—Technology of Cellulose Esters, vol. 8. 1916.

GIFTS.

American Society of Civil Engineers, Year Book. New York, 1916. (From the Society.)
Association of Railway Electrical Engineers, Proceedings, vol. 7. Chicago, 1914. (From the Association.)
Australia Commonwealth Bureau of Census and Statistics, Detailed Tables, vols. ii and iii, 1911. Melbourne, 1914. (From the Bureau.)
Baylor University, Catalogue, 1915–1916. Waco, Texas, 1916. (From the University.)
Canada Board of Railway Commissioners, Tenth Report, 1915. Ottawa, 1916. (From the Board.)
Canada Department of Mines, Memoir 58, Texada Island, B. C.; Memoir 72, The Artesian Wells of Montreal; Memoir 76, Geology of Cranbrook Map-Area, British Columbia. Ottawa, 1914 and 1915. (From the Department.)
Castigliano, A., Théorie de l'Equilibre des Systèmes élastiques et ses Applications. Turin, 1879. (From Mr. N. W. Akimoff.)
Clarkson College of Technology, Bulletin, vol. xiii, No. 1. Potsdam, 1916. (From the College.)
Connecticut Bureau of Vital Statistics, Sixty-seventh Registration Report, 1914. Hartford, 1915. (From the Bureau.)
Delaware College, Annual Catalogue, 1915–1916. Newark, no date. (From the College.)

France, Ministère de l'Instruction publique et des Beaux-Arts, Exposition Universelle et Internationale de San Francisco, La Science Française, tomes i and ii. Paris, 1915. (From the Ministère.)
Grand Army of the Republic, Forty-ninth Annual Encampment of the Department of Pennsylvania. Harrisburg, 1915. (From the State Librarian.)
Hartford Steam Boiler Inspection and Insurance Company, The Locomotive, vol. xxx, 1914 and 1915. Hartford, no date. (From the Company.)
Hungerford, U. T., Brass and Copper Company, Brass and Copper Catalogue. New York, no date. (From the Company.)
Lafayette College, General Catalogue, 1915-1916. Easton, no date. (From the College.)
Lehigh University, Register, 1915-1916. South Bethlehem, 1916. (From the University.)
Leland Stanford, Junior, University, Flugel Memorial Volume. Stanford University, 1916. (From the University.)
Music Trades Company, The Piano and Organ Purchaser's Guide. New York, 1916. (From the Company.)
National Association of Cotton Manufacturers, Transactions, 1915. Boston, 1916. (From the Association.)
New Bedford Board of Health, Annual Report, 1915. New Bedford, Mass., 1916. (From the Board.)
New South Wales Bureau of Statistics, Vital Statistics for 1914. Sydney, 1915. (From the Bureau.)
New South Wales Geological Survey, Department of Mines, The Composition and Porosity of the Intake Beds of the Great Australian Artesian Basin. Sydney, 1915. (From the Survey.)
New Zealand Government Statistician, Statistics for 1914, vol. ii: Shipping and Trade. Wellington, 1915. (From the Statistician.)
Nova Scotia Department of Public Works and Mines, Annual Report of the Mines, 1915. Halifax, 1916. (From the Department.)
Ohio Industrial Commission, Division of Mines, Fortieth Annual Report, 1914. Columbus, 1915. (From the Commission.)
Ontario Bureau of Mines, Twenty-fourth Annual Report. Toronto, 1915. (From the Bureau.)
Pennsylvania Chestnut Tree Blight Commission, Publications, 1911-1913. Harrisburg, 1915. (From the Commission.)
Pennsylvania Department of Mines, Report, 1914. Harrisburg, 1915. (From the State Librarian.)
Pennsylvania Insurance Commissioner, Forty-second Report, 1914. Harrisburg, 1916. (From the State Librarian.)
Pittsburgh, Cincinnati, Chicago and St. Louis Railway Company, Twenty-sixth Annual Report, 1915. Pittsburgh, 1916. (From the Company.)
Rose Polytechnic Institute, Thirty-fourth Annual Catalogue, 1915-1916. Terre Haute, Ind., no date. (From the Institute.)
Springfield Board of Water Commissioners, Forty-second Annual Report, 1915. Springfield, Mass., 1916. (From the Board.)
Titanium Alloy Manufacturing Company, Ferro Carbon Titanium in Steel Making. Niagara Falls, 1916. (From the Company.)

United States Coast and Geodetic Survey, Results of Observations made at the United States Coast and Geodetic Survey Magnetic Observatory near Honolulu, Hawaii, 1913 and 1914. Washington, 1916. (From the Survey.)

United States Navy Department, The Navy and Marine Corps Register. Washington, 1916. (From the Department.)

University of Missouri, School of Mines and Metallurgy, Catalogues, 1914-1915, 1915-1916. Rolla, no date. (From the University.)

University of North Dakota, General Catalogue, 1915-1916. University, no date. (From the University.)

University of Rochester, Annual Catalogue, 1915-1916. Rochester, no date. (From the University.)

University of the State of New York, State Museum, Sixty-seventh Annual Report, 1913. Albany, 1915. (From the State Librarian.)

University of Western Australia, Calendar, 1916. Perth, 1915. (From the University.)

Ursinus College, Bulletin, 1915-1916. Collegeville, Pa., no date. (From the College.)

Vanderbilt University, Register, 1915-1916. Nashville, 1916. (From the University.)

Wisconsin Geological and Natural History Survey, Bulletins, Nos. xxvii-xl, xliv, and maps, 1913-1915. Madison. (From the Survey.)

Yale University, General Catalogue, 1915-1916. New Haven, 1916. (From the University.)

BOOK NOTICE.

Catalysis and Its Industrial Applications, by E. Jobling, A.R.C.Sc., B.Sc., F.C.S. Philadelphia, P. Blakiston's Son & Company, 1916. 112 pages, contents and index. 12mo. Price, $1.

This is a very interesting and useful summary of some of the more recent applications of catalysis, especially in inorganic chemistry. After a brief discussion of the history of the subject and indications of the principal types of catalytic action, specific descriptions are given of the application in the manufacture of sulphuric acid, chlorine, nitrogen compounds from the atmosphere, surface combustion, and of the effect of the small proportion of ceria on the Welsbach mantles. The actions of catalysts in connection with the hydrogenation of oils, synthetic operations with coal-tar products, the nature of the "drying" of paints are discussed. The transformation of carbohydrates and proteins, under the influence of the well-known enzymes, is considered very briefly.

The book is a compact and valuable summary of an important field of industrial chemistry and will repay perusal both by the technologist and general chemist.

Henry Leffmann.

PUBLICATIONS RECEIVED.

Mining World Index of Current Literature, vol. viii, last half year 1915, by George E. Sisley, associate editor, *Mining and Engineering World*. An international bibliography of mining and the mining sciences compiled and revised semi-annually from the index of the world's current literature appearing weekly in *Mining and Engineering World*. 253 pages, 8vo. Chicago, Mining World Company, 1915. Price, $2.

American Telephone and Telegraph Company, Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1915. 58 pages, 8vo. New York, 1916.

U. S. Bureau of Mines: Bulletin 89, Economic Methods of Utilizing Western Lignites, by E. J. Babcock. 73 pages, illustrations, plates, 8vo. Bulletin 113, Abstract of Current Decisions on Mines and Mining Reported from May to September, 1915, by J. W. Thompson. 124 pages, 8vo. Washington, Government Printing Office, 1915–1916.

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CURRENT TOPICS.

Determination of Free Chlorine in City Water Supplies. G. A. LeRoy. (*Comptes Rendus,* vol. 162, No. 9, February 28, 1916.)—Water supplies in many towns are subjected to bacterial purification effected by the action of free chlorine, introduced in the form of alkaline hypochlorites, chloride of lime, or Javel water. Quite apart from any injurious effects on the system of free chlorine in drinking water, the odor and taste of water containing a greater quantity of free chlorine than 0.05 mg. per litre are objectionable. Hence the chemical control of waters so treated is important. Unfortunately the usual methods for the determination of free chlorine in water are inefficient and inoperative when the quantity of chlorine per litre falls below 0.05 mg. The method here proposed, capable of determining much smaller proportions of chlorine, is based on the partial freezing and concentration of the water to be examined. In freezing, the water separates as pure ice, leaving the chlorine concentrated in the remaining small quantity of uncongealed water. Under these conditions, using 10 litres of water, it is easily possible to estimate with starch-iodide mixture reagent 0.0005 mg. per litre.

This qualitative method may be made quantitative by precise determination of the original quantity of water and that uncongealed, and subjecting the latter to colorimetric comparisons with standard titrated solutions.

Propelling Machinery for Ships. W. J. Drummond. (*The Journal of the Institution of Mechanical Engineers,* March, 1916.)—When deciding on the type of machinery to be adopted in any ship, the most important general features are: reliability, economy of fuel, ease in manœuvring, and weight in relation to the power developed, the latter being particularly important in the case of warships. Above all other considerations, however, reliability must take precedence.

The engines of a ship often have to run without a stop for forty or fifty days, and the safety of the ship depends entirely on the ability of the engines to do the work required of them in a heavy sea and under circumstances never met with in land practice.

By far the commonest type of machinery afloat is the three-crank, triple-expansion condensing engine, supplied with steam by cylindrical boilers, and it is to-day a highly efficient piece of machinery. As compared with turbines, in two recent battleships in the United States Navy of about 20,000 horse-power, one equipped with turbines, the other with reciprocating engines, the reciprocating-engined vessel maintains a distinct lead in economy of fuel. An arrangement which is the logical outcome to use steam down to as low a

pressure as possible, and has been used successfully on many of the largest steamers built, consists of two triple-expansion engines taking steam direct from the boilers and exhausting into a low-pressure turbine. In many cases the turbine receives steam at less than atmospheric pressure and develops from one-quarter to one-third the total power. When the vessel is under way astern, the turbines revolve *in vacuo*, the steam from the reciprocating engines passing direct to the condensers.

In England, the direct-coupled turbine in large, high-speed vessels more than holds its own, compared with reciprocating engines, and efforts are principally directed towards adapting them to slower-speed vessels. To do this successfully, the propeller must run at 80 to 200 revolutions, while for maximum efficiency the turbine must run at 2000 to 3000 revolutions. Geared turbines have been employed to meet these conditions, and in several cases of direct comparison with vessels fitted with triple-expansion engines the geared turbine vessels have shown superior economy of fuel. One of the objectionable features of the early geared turbines was the noise. By careful design and workmanship noise and vibration have been much reduced.

The two chief rivals of mechanical gearing are the Föttinger transformer and the electric drive. The Föttinger transformer has been developed in Germany by the engineer whose name it bears. It consists, briefly, of a high-speed turbo-centrifugal pump and two water-turbines designed to run in opposite directions and at a lower speed of rotation than that of the pump. These are all incorporated in one casing; the steam-turbine drives the pump, the water from which drives either water-turbine at will, both being rigidly connected to the propeller shaft. This device possesses great flexibility, but its efficiency is considerably lower than the geared turbine, being 90 per cent., as against 98½ per cent. for the hydraulic gear.

The electric drive has had its chief development in the United States, a successful installation in the collier *Jupiter* having demonstrated the feasibility of installing the system in the battleship *California*. Possible danger from faulty insulation and increased complication are the chief objections to this system.

Boilers on board ship fall into two main divisions—ordinary cylindrical or Scotch boilers, and the numerous types of water-tube boilers. From a naval point of view the cylindrical boiler takes up too much room, is not sufficiently adaptable to rapid variations demanded in the supply of steam, and takes too long to raise steam. With water-tube boilers on turbine-driven destroyers, the time of getting under way, starting from a cold ship, is that necessary to warm the turbines thoroughly, and has been known to be as little as twenty minutes.

Oil fuel is in limited use for steaming purposes, mainly in warships. For steaming purposes it has the important advantage of meeting large and sudden demands for power. A type of engine

which may make the use of oil fuel more general in the merchant service is the Diesel. A limited number of Diesel engines have been fitted on board ship, but they are all of comparatively low power.

An Enclosed Cadmium-vapor Arc Lamp. H. J. S. SAND. (*Proceedings of the Physical Society of London*, vol. xxviii, part ii, February 15, 1916.)—The yellow sodium doublet and the lines emitted by the mercury-vapor arc have hitherto usually been employed in those branches of physical inquiry in which a powerful light of well-defined wave-length was needed. The great importance of having further lines at our disposal, particularly for the measurement of rotary dispersion, has been emphasized recently by Lowry, to whom we owe the introduction of the mercury arc in polarimetric work; and the use of the cadmium lines was recommended by him.

The author's design of a cadmium-vapor lamp is the product of several years' experience gained in attempts to construct such a lamp that would meet the requirements of a laboratory appliance as completely as possible. The lamp is constructed of quartz glass and, in general construction, is similar to the well-known mercury lamp. It consists essentially of a quartz tube bent into an inverted U in such a manner as to form a short cathode chamber and a long anode chamber. To start the lamp, the metal is melted by means of a Bunsen burner, and the arc is struck by tilting. Before introduction into the lamp, the metal is freed from oxide and dissolved gases by a special process of filtration while at the pump. When started from the cold it usually lights up even before tilting. It was generally run on a lighting circuit of 100 to 200 volts, with a back resistance adjusted to a current of 5 to 7 ampères on short circuit. The potential difference at the terminals of the lamp is low, usually about 30 volts. The metal distils over from the lower hotter anode chamber into the upper cathode chamber and the metal drips back again over the bend of the U every two or three minutes, causing a slight flicker which, however, does not interfere with the use of the lamp. The metal is prevented from adhering to the glass, which might lead to fracture, by the pressure of a small amount of loose powder (zirconia) in the lamp. When once started the lamp will continue to burn indefinitely and gives a powerful light.

Photographs in Relief. E. CONSTET. (*Revue Generale des Sciences*, 27th year, No. 4 February 29, 1916.)—In 1899, Andresen pointed out the property possessed by hydrogen peroxide of dissolving both the reduced silver and the gelatine substratum of a photographic plate. This effect, however, sometimes took place very slowly, even with very concentrated hydrogen peroxide, 15 to 24 hours being required. The author has demonstrated that the action may be made to take place in a few minutes if several drops of acetic acid are added to the peroxide bath or if the bath is composed of water, 100 c.c.; hydrochloric acid, 10 c.c.; barium dioxide, 4 gm.

The dissolution of the image takes place in a selective manner, the dense parts of the image being more readily attacked than those containing a proportion of the unreduced salts. This action results in the formation of an image in relief inversely proportional to the opacity of the metallic deposit. Another bath for producing this effect has been patented by Belin and Droillard, consisting of hydrogen peroxide to which are added nitric acid, sulphate of copper, and bromide of potassium (French patent No. 423,150).

If the negative has not been previously fixed in hyposulphite, a positive image is obtained, the differences of shade being represented by varying thicknesses of unattacked gelatinobromide of silver. By simple absorption of aniline colors the positive image may be made to assume any tint. The thick parts of the gelatine relief absorb a relatively considerable quantity of the coloring matter, and the thin parts proportionally less. Prints on paper can be obtained from such a colored relief plate while damp by simple contact. To this end, a paper coated with a thin layer of hard gelatine is employed; for example, that known as *simple transfer* in the carbon process. Two or three prints may be so obtained from one soaking in the color-bath, after which the plate must be returned to the bath for an additional supply of color. Photoprinting plates may also be made from the relief by the stereotype process.

Optical Appliances in Warfare. C. R. DARLING. (*Journal of the Royal Society of Arts,* vol. lxiv, No. 3303, March 10, 1916.)—Optical appliances used in warfare comprise a large number of separate items, but those which are of paramount importance in military operations and in general use may be classified as follows: (1) Field-glasses and telescopes; (2) searchlights; (3) periscopes; (4) range-finders; (5) signalling lamps and heliographs. In addition to these, cameras, prismatic compasses, surveying instruments, etc., are used, but only those devices especially devoted to warfare embraced in the above five headings will be considered.

As an aid to vision, field-glasses or telescopes are essential in military operations, and a number of different patterns, varying according to circumstances, are in use. Binoculars on the principle of the Galilean telescope possess several drawbacks as compared with modern prismatic glasses, notably that the field of view is small and the magnification low, and also that cross-wires cannot be introduced, owing to the fact that no real image of the object is produced. On the other hand, they give good illumination, and in a dull or dark atmosphere may be used to advantage. Patterns with magnifying powers of three, four, and five respectively are in use, having fields of view ranging from about 3° to 4° 30′.

The prismatic binoculars introduced by the firm of Zeiss have the advantage of a long-focus object-glass mounted in a short body, an increased field of view by placing the object-glasses farther apart than the eye-pieces, and that a real image of the object is formed, enabling

cross-wires or graticules to be used. Patterns are issued with magnifying powers of six and eight, with fields of view ranging from 4° 40′ to about 8° 30′, a marked advantage over the Galilean type. In some of these, graticules are fitted in the focal plane of the object-glass. These consist of a number of lines ruled on a glass plate, spaced out so as to represent minutes of deflection to right or left, which assist in accurately determining the position of the object in the field of view. If rotated through a right angle, the graticules may be used similarly for elevated objects, the dimensions of which may be thus estimated.

A number of different kinds of telescopes, fitted with special devices, are used either for general observations or as distinctive parts of instruments, such as directors on gun-sights, the magnifying power ranging from three to thirty-five. In some patterns the magnification may be varied over a wide range—from five to twenty diameters—by a single movement, without disturbing the focus of the sighted object. When telescopes are used for gun-sights, a pointer or sighting-wire is placed in the focal plane of the object-glass where the image of the target will be formed, and when the image is seen to coincide with the assigned mark the aim is correct. This method of sighting is preferable to the alignment of the target with the fore-sight and back-sight, as the eye cannot be focussed upon all three points at once.

The searchlight does not play a prominent part in land warfare under present conditions, as it would be too conspicuous an object, and when illumination is required star-shells are used. As a means of sighting air-craft, for coast defence, and for naval purposes, however, the searchlight is indispensable. The source of light is an electric arc at the focus of a concave mirror. As the focus of the mirror is a point, it is evident that only one point of the crater of the arc can occupy this position, and rays emanating from this point, after reflection, will proceed in lines parallel to the mirror. From all other positions of the crater the rays will be reflected from the mirror at an angle with the axis, the value of which under working conditions is 2 or 3 degrees. Although glass mirrors, silvered on the back surface, by which spherical aberration is corrected, have been used, they have been abandoned on account of their liability to breakage, and paraboloid mirrors made of metal are now used, the reflecting surface being of silver or gold, or occasionally of palladium or nickel.

The combination of two 45-degree mirrors mounted in a frame, used for viewing over a parapet without exposing the observer, is frequently referred to as a periscope. Strictly speaking, a periscope is an instrument in which the entire horizon may be viewed through a fixed eye-piece. For naval work, and particularly for submarines, these instruments are invaluable, as observations may be made with nothing but the top of the instrument projecting above the water. A periscopic gun-sight also enables guns to be laid under cover, and enables auxiliary marks to be used without the gunner having to

change his position. In principle it consists of a vertical tube containing reflecting prisms and an objective. Horizontal light-rays are reflected vertically downwards, then horizontally to an eye-piece.

Range-finders, in principle, depend generally upon the estimation of the distance of the target from a point in a base line of known length. Knowing the bearings of the target from the extremities of the base line, the lengths of the other sides of the triangle can be either determined by computation or by a direct calibration of the angular setting into orange when one of these angles is a right angle. The instrument most widely used for range finding is that of the type introduced by Professors Barr and Stroud. It gives satisfactory results as to accuracy, and is compact, having a total length of less than four feet. It has also the very considerable advantage of requiring only one observer. The trigonometric principle is also employed in this instrument. The base line is the distance between two objectives at the end of a tube which form two separate images, one erect, the other inverted, separated by a horizontal line, and viewed by an eye-piece at the centre. Coincidence of similar points of the two images at the line of separation is secured by the movement of a prism in one side of the optical system. The amount of this movement is a function of the range which is read from a calibrated scale adjacent to a pointer attached to the movable prism.

In trench warfare, signalling by flags, heliograph, or lamps is not generally resorted to, the field telephone being better adapted for communication under these conditions. In open warfare, however, the heliograph is useful for flashing signals by the aid of sunlight. It consists of a circular flat mirror, five inches in diameter, capable of being tilted through a small angle by means of a key, and possessing a sighting-vane for laying on to the receiving station. The Morse code is used, short flashes representing dots, and sustained flashes dashes. For night work signalling lamps are used, a parallel beam of light being sent out which can be cut off by a movable shutter.

Potash from Kelp. I. F. LAUCKS. (*Metallurgical and Chemical Engineering,* vol. xiv, No. 6, March 15, 1916.)—The scarcity of potash due to the war has caused great interest to be taken in many of its possible sources. One of these is the growths of kelp on the Pacific coast. Much has been written on the subject, but very little information is available on the gathering and treatment of this material to transform it into a marketable product. Before this year most of the companies attempting to develop the kelp industry have been of limited capital. Only lately have several concerns with adequate resources to carry on their development to a successful issue engaged in the industry, so that at the present time a limited amount of dried kelp is being produced, and very considerable increase in this production may shortly be expected. The author has had direct charge of large-scale operations, harvesting, transporting, and drying kelp, and his records are the results of actual experience.

This experience has been confined entirely to the kelp of Puget Sound, but, outside of the composition of the plants, most of the experience would be applicable to California kelp as well.

The green kelp plant is mostly water, analyses having shown as high as 95 per cent. water. The average is probably between 92 per cent. and 93 per cent. The important question in the utilization of kelp has always been the cost of harvesting. There was no reliable way of prophesying what it would cost to go out in the ocean, cut a plant below the surface of the water, get it aboard a scow, and land it. The other features of the process were well known. Data on drying costs, leaching, crystallizing, etc., were available, but no one had ever before harvested a marine plant in hundred-ton lots. There have been a number of different types of machines proposed for cutting kelp, including reciprocating knives, revolving blades, band saws, etc., but, so far as the writer is aware, the only method that has been tried in actual practice is that of reciprocating knives (like a mowing machine). These operate several feet below the surface of the water and may be made as wide as desired. A conveyor of some type is usually placed behind the knives to carry the cut kelp aboard the scow. After it is aboard it is generally chopped into shorter lengths by various machines, and piled either on the scow which carries the cutting mechanism or on another scow alongside. The cost of harvesting with an equipment of this kind amounted to 43 cents per ton, which includes the relatively large towing charge of 32 cents per ton. The latter can be reduced considerably by mounting the cutting machinery on a self-propelled barge. Unloading by hand costs 6.3 cents per ton, but this can be reduced to less than 1 cent per ton by the installation of a conveying system on the deck of the scow. The cost of drying will vary between 25 and 50 cents per ton of green kelp, depending on the fuel used, cost of power, size of plant, etc.

It is not necessary to go further than the dried kelp to obtain a marketable product. The potash and nitrogen are salable on a unit basis. Assuming 28 per cent. chloride of potash and 2 per cent. nitrogen in the dried material, about 60 per cent. of the weight is practically valueless. If the material is shipped from the Pacific coast to the Atlantic by water, the nitrogen will just about pay the freight in ordinary times. If the potassium chloride is concentrated from the balance, the nitrogen can be sold on the Pacific coast and 70 per cent. of the freight saved on the potash. With the present high price of potash, the drying of kelp is a very profitable business. Such conditions will enable the industry to get a start and work out its problems. With normal prices of potash, kelp must be worked in plants of large capacity, well designed, with a minimum of labor, every possible economy effected, and all of the profitable by-products saved. It would seem unlikely that the price of potash will be lower for some time than it was before the war. If the price remains above $35 per ton for 80 per cent. muriate of potash, kelp can be worked at a profit in a properly-designed plant.

Fuel Briquet Industry in 1915. ANON. (*U. S. Geological Survey Press Bulletin*, No. 267, April, 1916.)—Over a million dollars' worth of briquets were made out of waste coal dust in 1915, the exact production being 221,537 short tons, valued at $1,035,716. This was the largest output in the United States for any year with the exception of 1914. The manufacture of this type of fuel is, however, still in its infancy, and according to C. E. Lesher, of the United States Geological Survey, a good many years will probably elapse before the briquet industry assumes very large proportions. The work of briquetting this low-grade material and converting it into fuel suitable for higher uses is, however, practicable conservation, and as such deserves far more attention than it now receives in this country. European countries, more thrifty in their use of coal, have developed the briquetting industry to large proportions. Most of the mechanical difficulties of manufacture have been solved in this country, and the future growth of the industry now depends upon the development of markets for the product. The producing plants are, however, so widely distributed and the total production is so small compared with that of other kinds of fuel that the conditions affecting the market for the output of each plant are more or less local and peculiar. In general, in the East, briquets compete with anthracite as domestic fuel, and nearly all the output of the eastern plants is manufactured from anthracite culm. The people of the eastern cities, accustomed to the incomparable anthracite, have not taken very kindly to these briquets, probably largely because of the volume of tarry smoke given off by nearly all kinds of briquets when they are first ignited, and perhaps partly because it has not been possible to offer them at a price enough lower than that of anthracite to induce their extended use. Being made from the cheaper sizes of anthracite, the briquets contain a greater amount of ash than the domestic sizes, and, although this ash does not clinker in the furnace, it reduces the heat value of the fuel.

There were 15 briquetting plants in operation in the United States in 1915, one less than in 1914. One new plant in California reported an output in 1915, and two plants, one in New Jersey and one in New York, ceased operations. The greatest increase in output was made on the Pacific coast, the central states recording little change and the eastern states a large decline in output.

Strontium in 1915. (*U. S. Geological Survey Press Bulletin*, No. 267, April, 1916.)—The manufacturers of red fire and of beet sugar are said to have shown considerable interest in domestic strontium deposits during the last year. If sugar holds its present price the beet-sugar makers might perhaps profitably substitute the strontia method for the one they now use, but the substitution will require considerable time and its economy must depend on several economic factors which are unknown to the United States Geological Survey, by

which the statistics of the industry are compiled. The returns received by the Survey do not show that any strontium-bearing ores of domestic origin were sold in 1915 or that any American deposits were exploited.

The deposits in northwestern Ohio and southeastern Michigan seem to be the best available for early exploitation. Celestite, a strontium mineral, is reported to occur in workable quantities in certain limestone quarries near Toledo, Ohio, though it is not now recovered. The mineral is found in broken and open beds of dolomite, or magnesian limestone. The installation of expensive machinery for its recovery is hardly warranted, but the larger pieces of celestite could be easily hand-sorted from limestone on picking belts, or possibly on the ground, and would probably find a market.

Large deposits of celestite occur in Arizona and California, but they are far from markets and of low grade as compared with commercial ores now used. Plants for making commercial strontium compounds may eventually be built at places where both these sources could be drawn upon, but the development of these deposits must wait on the decision of the sugar refiners to adopt the strontia process.

Most of the commercial ores used in making strontium salts are of high grade, containing at least 95 per cent. strontium sulphate. English celestite is at present largely used on the eastern seaboard and is laid down at the works at about $12 a ton, so the owners of deposits of strontium ores must not hope for large profits on their crude material.

The principal commercial strontium salts are strontium hydroxide, used in the beet-sugar industry, and strontium nitrate, used in pyrotechnics, in which, however, strontium chloride is also used. Small quantities of certain organic and inorganic salts, such as acetate, lactate, bromide, iodide, arsenite, and phosphate, are used in medicine.

Strontium nitrate was formerly used in making some types of smokeless powder, but the powder companies, it is said, now use the salts of strontium only for making illuminating or signal shells, in which the value of the strontium lies in the brilliant red color it imparts to the flame produced by explosion.

The imports of strontium oxide, protoxide of strontium, and of strontianite, or mineral carbonate of strontia, in 1914, as reported by the Department of Commerce, were valued at $1016, and in 1915 at $6411. The imports of celestite (strontium sulphate) used by domestic manufacturers of strontium salts are not recorded, as this mineral is classified with other chemicals not specially provided for. Strontium salts are imported free of duty.

The United States Geological Survey has now in press a report by J. M. Hill on barytes and strontium in 1915, a copy of which may be had, when issued, on application to the Director, United States Geological Survey, Washington, D. C.

Preparation of Tungstic Metals. H. FLECK, before the Colorado Scientific Society. (*Mining and Scientific Press,* vol. 112, No. 4, January 22, 1916.)—The metal is prepared in two forms; namely, powder and ferro-tungsten alloy. Much discussion has arisen regarding their respective advantages, especially with reference to the relative waste incurred during introduction of each form into the steel bath. Apparently no decision has been reached, since both forms are manufactured, although about 85 per cent. of the tungsten is made into the ferro-alloy. Powdered tungsten is fed into the bath by means of an enclosure in steel tubes, in order to prevent oxidation of the tungsten. The manufacture of powdered tungsten first demands a preparation of tungstic trioxide from the ore and then reduction at high temperature with some pure form of carbon. A rather coarse, steel-gray, dense tungsten results, which, with care, may have its carbon content kept within 1 per cent.

Ferro-tungsten is made mostly from the concentrate direct by electric-furnace treatment. It contains from 50 to 80 per cent. tungsten. Carbon, in the form of coke, is the common reducing agent. Hematite is used subsequently as a decarbonizer.

Portable Equipment for Thawing Frozen Pipes. ANON. (*Electrical World,* vol. 67, No. 12, March 18, 1916.)—A gasoline engine directly connected to a low-voltage direct-current generator, a switchboard, and a reel of cable assembled on a small truck make up an outfit that is being effectively used by the water-works department of the city of St. Paul, Minn., to thaw out frozen water pipes. The generator is rated at 20 kilowatts at 40 volts, and is driven by a four-cylinder, four-stroke-cycle gasoline engine. A voltmeter, an ammeter, a rheostat, and a single-pole knife switch of 500 ampère rating are mounted on the switchboard. The reel holds 500 feet of flexible copper cable of 300,000-circ. mil. cross-section in 100-foot lengths. Each length is fitted with terminal lugs. The various parts are attached to a steel frame, which is mounted on a 1.5-ton trailer hauled by a motor truck. The mounting is temporary, so that after the winter season the thawing unit may be removed and the trailer used for other purposes.

In operation, the positive terminal of the generator is connected through a section of the cable to the frozen pipe in the building between the meter and the street main and the negative terminal to the nearest outside fire hydrant, so that the circuit is through the lead or iron service pipe and the main to the hydrant. After the cables are connected, the engine is started and the voltage built up to between 30 volts and 40 volts, when the main switch is closed. A current flow of about 250 ampères is maintained for two or three minutes and then increased to 350–500 ampères, depending upon how badly the pipe is frozen. Under these conditions it is reported that the service line has been cleared in all cases within ten minutes.

The Pipe- and Reed-organ Industries. J. C. FREUND. (*The Piano and Organ Purchasers' Guide* for 1916.)—Pipe-organs (almost invariably for churches) were built long before an effort was made by Americans to construct reed-organs. Up to about fifty or sixty years ago we still imported most of our reed-organs, melodeons, or harmoniums, principally from France. About 1850, however, the American reed-organ manufacture really began and soon surpassed the European product in importance and quality. The church- or pipe-organ industry has also made great progress, and we have manufacturers who design and erect instruments that can compare favorably with the best made in England, France, Germany, and Italy—countries which long enjoyed supremacy in this product. The extraordinary improvements in reed-organs from the days of the old primitive melodeons have acted somewhat as a bar to progress in church-organ building, particularly as the cheaper price of the reed-organ made it more popular in communities where economy is a serious object in purchasing an instrument for a church or chapel. Recently, however, great strides have been made by the western as well as the eastern church-organ builders. Electrical mechanism has been extensively developed, and with it corresponding economies in manufacture have enabled the builders to lower costs.

Most of the notable improvements and inventions in church-organ building have been made by Americans. Up to the year 1835 the reed-organ industry in the United States had made no great progress, such factories as there were being confined to Boston and the New England towns. For a long time the East controlled the market in reed-organ making, but later the West became a great reed-organ producing territory, with Chicago as the centre. By the year 1870 the American reed-organ had driven foreign instruments out of the market.

The two radical improvements from whose invention dates the superiority of the American reed-organ are, first, the discovery that by giving the tongue of the reed or vibrator a peculiar bend or twist the quality of the tone was improved. This process is known as "voicing." Previous to this all reeds had been left flat or straight, so that the tone produced was thin and reedy, as in the foreign-made instruments. The second improvement was in the substitution of an exhaust system for the pressure system used by the English, French, and German instruments. Some houses of distinction have of late years brought out reed-organs of large size which are only surpassed in volume and beauty of tone by the larger pipe-organs. Constant efforts have also been made during the last twelve or fifteen years to produce self-playing organs, using perforated rolls similar to those of the piano-player, and within the last few years these efforts have met with marked success.

Rapid Nickel Plating. O. P. WATTS. (*Proceedings of the American Electrochemical Society*, April 27-29, 1916.)—During the greater part of the half century that nickel plating has been practised, platers were content to follow in the footsteps of their forefathers and deposit nickel at the slow rate of three to five ampères per square foot. A few years ago " rapid nickel salts," claimed to permit nickelling at two to three times the usual rate, were imported from Europe. These proved to be mixtures capable of yielding more concentrated solutions than that enemy of progress, the " double sulphate," which for so long has masqueraded as the plater's friend. The American plater soon learned how to make up his own rapid solution, and as a result nickelling at ten to twenty ampères per square foot is very common to-day.

Recent achievements in plating with cobalt at 150 ampères per square foot, turning out commercial plating of high grade in three minutes, suggested the desirability of obtaining similar effects with the cheaper nickel solution. In so far as the wonderful results in cobalt plating depend upon the extreme concentration of the solution (312 grammes of anhydrous cobalt sulphate per litre), it should be possible to duplicate them with nickel, since its salts are equally soluble. It is in the matter of anode corrosion and in its absorption of hydrogen that nickel is inferior to cobalt as a metal for electroplating. The nickel anode becomes " passive " on the slightest provocation, and, instead of all the current dissolving nickel as desired, a portion of it is spent in producing acid at the anode. Besides cutting down the efficiency of deposition, this acid causes hydrogen to be evolved in considerable quantity on the cathode, where some of it is absorbed by the deposit. Absorption of hydrogen by nickel renders it hard and brittle, and is likely to cause it to curl away from the metal on which it is deposited. The addition of a small amount of chloride to the sulphate solution usually used for nickel plating is a well-known remedy for this passivity of the anode.

Previous experience with hot nickel solutions indicated their use for overcoming the difficulties mentioned, since, in hot solution, anode corrosion is greatly improved and absorption of hydrogen lessened. (1) Heating from 25° to 70° C. lessens the resistance of the solution one-half. (2) The current density may be increased two and a half to three-fold. (3) If less than 100 per cent. in the cold solution, the current efficiency is raised. (4) Anode corrosion is greatly improved and higher current densities may be used at the anode as well as at the cathode. (5) The deposit is superior to ordinary nickel plate in toughness and freedom from peeling. (6) In the solution tested, plating may be done at 200 to 300 ampères per square foot, at which rate the same amount of metal is deposited in five minutes as requires one and a half hours in the " rapid solutions " now in use at ten ampères per square foot.

Getting Potash from Brines. ANON. (*United States Geological Survey Press Bulletin,* No. 233, March, 1916.)—The urgent need of a domestic supply of potash salts has greatly increased since the importations from Germany were stopped. During this time the price of high-grade potash has advanced from $39 to about $500 a ton. Meanwhile efforts to find commercially workable deposits of potash in this country have been eagerly and diligently made, both by private capitalists and public agencies. The United States Geological Survey, appreciating the needs of the manufacturers and farmers of this country, has endeavored both to find deposits of soluble potash salts and to discover practicable methods of extracting potash from rocks that carry relatively large proportions of potassium. Every clue that might yield valuable results has been followed up in a country-wide investigation, extending from New York to California. The Geological Survey, in its search for potash, has sunk several deep holes in the deserts of Nevada and is now drilling one in the panhandle of Texas.

The Geological Survey is also making some laboratory experiments designed to aid in discovering a cheap process of separating potassium salts from natural brines. In these experiments special attention has been given to the evaporation of brines rich in potassium. The results of some of the earlier work were published late in 1915 as Professional Paper 95–E. More recent experiments have been made with the natural brine from Searles Lake, Cal., which contains the equivalent of nearly 12 per cent. of potassium chloride in the solid salts. The results are given in a recent Survey publication, "Evaporation of Brine from Searles Lake, Cal.," by W. B. Hicks, issued as Professional Paper 98–A. This report shows the changes in the composition of the solution resulting from the evaporation of the brine, the composition of the crystals deposited from the hot solution during evaporation, and the composition of the crystals deposited when the solution was cooled. A copy of the report may be obtained free of charge by addressing the Director, United States Geological Survey, Washington, D. C.

The data recorded indicate that carefully-controlled fractional evaporation and crystallization, possibly combined with other treatment, promise much as a means of obtaining potassium from brines similar to that of Searles Lake. Further study of the behavior of the constituents of the brine under varying conditions may be made.

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REFINING VEGETABLE AND ANIMAL OILS.*

BY

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The terms "fat" and "wax" are commonly applied, more or less indiscriminately, to solid substances which have a greasy feeling to the touch and do not dissolve in water. Physically, waxes are regarded as having generally a harder consistency than fats. Chemically, fats are usually compounds of the trihydric alcohol, glycerol, $C_3H_5(OH)_3$; while the waxes are compounds of monohydric alcohols of large molecular weight; for example, cetyl alcohol, $C_{16}H_{33}OH$; myristic alcohol, $C_{30}H_{61}OH$, and cholesterol, $C_{27}H_{45}OH$. The names applied to some of these substances do not lessen the confusion; for example, "wool fat" and "spermaceti" are compounds of cholesterol and cetyl alcohol, hence are in reality waxes; while "Japan wax," a compound of glycerol, is actually a fat.

A fat, such as is indicated above, has among other physical properties a characteristic melting-point. Those which are liquid at ordinary temperatures are called *oils*. It is of such substances more especially that this communication deals with, although reference will be made to cocoanut oil, which may or may not be a solid at ordinary temperatures, therefore technically might be regarded as a fat.

* Presented at a meeting of the Section of Physics and Chemistry held February 10, 1916.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

It will be understood that the term "oil," as here used, is not to be associated with the natural or petroleum oils, *i.e.,* hydrocarbon oils, or the essential oils, both classes of which in generai exhibit in a way the physical but not the chemical properties, necessarily, referred to above.

Fats are widely distributed in the vegetable and animal kingdoms, and, referring to the former only for the time being, we may say they are primarily glycerides of oleic, palmitic, and stearic acids. These fats are found *mainly,* but not necessarily, in the reproductive bodies, such as spores and seeds. They are found in spores, sexual and asexual, of many algæ. In angiosperms they are widely distributed, replacing, wholly or in part, carbohydrates as reserve food material, and they are often associated with protein reserves; for example, in the seed from which colza oil, palm oil, cotton-seed oil, linseed oil, olive oil, and cocoa butter are obtained. It is present, perhaps, as a reserve food material, associated with starch, in some tubers. The starch in the parenchyma of the stem of certain plants may be converted into fat during the winter's cold, and *vice versa,* when there is a rise of temperature in the summer time. Without venturing into the misty etiology involved, we may, for our purposes, realize the likelihood of the presence of carbohydrates, proteins, and other substances derived therefrom, as gums, etc., in oils obtained from these sources by the various means to be referred to later.

These oil-containing bodies invariably contain some coloring matter. Some of the coloring matters appear to be essential for certain of the changes just referred to. The most prominent pigment appears to be chlorophyll, an ester of tricarboxylic acid, chlorophyllin, $C_{31}H_{39}N_4Mg(COOH)_3$, and is the normal green coloring matter of plants. It may easily be broken down into substances that contain magnesium and substances that do not contain that metal.

Accompanying the chlorophyll are several pigments more or less insoluble in the cell sap; namely, carotin ($C_{40}H_{56}$), yellow to red in color, and xanthophyll ($C_{40}H_{56}O_2$), a neutral body, yellow to orange in transmitted light. These substances may be destroyed by the action of such powerful chemical agents as concentrated sulphuric acid, especially if heated in the presence of oxygen.

Closely related to the fats is a group of substances known as phosphatides or lecithins. Occurring in egg-yolk to about 9 per

cent., we find them to the extent of from 0.25 to 1.75 per cent. in cereals and leguminous seeds, hence they appear in the oils extracted from the seed. They are glycerol esters, two of the acidities being neutralized by fatty acids, the third being saturated by a combination of phosphoric acid and choline, as shown here.

$$\begin{array}{l} CH_2O_2C.C_{17}H_{35} \\ | \\ CH\,O_2C.C_{17}H_{35} \\ | \\ CH_2-OP.O.OH.O.\ C_5H_{13}N,\ OH \end{array}$$

It is easily broken up by lipase, and hydrolyzed by boiling with alkalies and acids.

We always also find a small quantity of unsaponifiable residue in fats, which is in the main composed of the monohydric alcohols, cholesterol, $C_{27}H_{45}OH$, and phytosterol, the latter now being a generic term for a group of allied substances, with formulas varying from $C_{27}H_{45}OH$ (sitosterol) to $C_{30}H_{47}OH$ (stigmosterol). Cholesterol occurs in the bile, brain, and blood of animals, and is the chief alcohol constituent of wool-fat. All vegetable fats contain phytosterol, the amount varying from 0.1 to 0.3 per cent., being even higher in the oil obtained from certain peas and beans, especially Calabar beans.

The oils are extracted by disintegration of the mass involving a disruption of the oil-sacs: (*a*) with a suitable solvent; (*b*) rendering by heat, with or without water; (*c*) or pressure, mechanical, applied when the mass is cold or hot.

If the mass extracted be selected and perfectly clean and fresh, the oil or fat obtained is usually neutral and "sweet." The exigencies of commercial operation do not admit of these conditions, however, so the oil or fat produced is usually acid and more or less contaminated. The contaminations may be quite normal and natural. They may be bacterial in nature and also contain the very interesting substances known as enzymes (lipase, for example) which induce hydrolysis; that is to say, they will cause any water present to disintegrate the fats (and other bodies) into simpler bodies. This may be facilitated by exposure to air and light, so that a freshly-expressed oil that is sweet may soon acquire an unpleasant taste and odor. In some cases we say it becomes

rancid, but in all cases the oil develops acidity, and the amount of the acidity of a particular oil is a function of time.

Under favorable conditions—and they are usually favorable—these changes take place within the oil-containing bodies, so that freshly-produced oil is usually acid, which acidity increases on keeping. The enzymes are "killed," or decomposed, or at least their directive activity ceases, when they have been exposed to a temperature of about 200° C. It has not been considered a good procedure by the practitioners of the art of oil extraction and refining, however, to heat the oil to such a temperature immediately after its production; but I venture the opinion that the increased development of acidity in crude oil in storage or in transit to a refinery will be materially affected by such treatment. However, it will be necessary to be assured that substances charred or scorched at that temperature are absent.

As mentioned above, oils and fats are primarily glycerides of the saturated palmitic ($C_{16}H_{32}O_2$) and stearic ($C_{18}H_{36}O_2$) acids, associated with the fatty acids of several unsaturated series. For example:

1. Oleic acid, $C_{18}H_{34}O_2$, type $C_nH_{2n-2}O_2$.
2. Linoleic acid, $C_{18}H_{32}O_2$, type $C_nH_{2n-4}O_2$.
3. Linolenic acid, $C_{18}H_{30}O_2$, type $C_nH_{2n-6}O_2$.
4. Clupanodonic acid, $C_{18}H_{28}O_2$, type $C_nH_{2n-8}O_2$.
5. Ricinoleic acid, $C_{18}H_{34}O_3$, type $C_nH_{2n-2}O_3$.

The last is an hydroxy acid, which undergoes a particular polymerization under suitable conditions.

Most fatty oils, on exposure to the air, tend to thicken, due partly to oxidation and partly to polymerization, or both. Oils are, in fact, classified by many according to their drying qualities and tendency toward resinification. These properties play an important part in their utilization in the arts; and their treatment in refining is materially affected by the time which may have elapsed from actual production to their refining. For example, a freshly-produced linseed oil may be profitably refined by a process which is inapplicable if the oil be "aged oil."

Oil, as stated, is normally a liquid, and we usually associate the phenomena of solution with a liquid. To be sure, this is a restricted conception, but will answer for our purposes. In this connection oil acts like water as a fluid. Water in motion carries

fine particles suspended through long distances and deposits them in time, when fairly quiet, as we know from the formation of alluvial soils. Water carries certain substances in solution. These latter substances are sometimes colored and are partly fixed on the filter when that water passes through certain filtering media. For instance, we are able to adsorb Congo red from a water solution with filter-paper. Again, water carries certain substances which do not stop on the filter; they are invisible and show themselves only when we apply the ultra-microscope. These finely-divided substances, not small enough to be in actual solution, will remain suspended in the water for long periods of time. They are called colloids. By various means, through heat, addition of an acid, an alkali, or a salt, by the influence of an electric current, or by the addition of other colloids, these very finely-divided substances may be caused to agglomerate; that is, they may be converted into particles of sufficient size to be separated from the fluid by means of a filter. Exactly the same is true of oils. Organic colloid solutions may be viscous; the liquid particles are suspended in a liquid medium.

Many of the contaminating substances, referred to here in general, may be suspended in the oil, may be in solution in the oil, or may be in a colloidal condition in the oil.

It will, therefore, be quite apparent that crude vegetable and animal oils contain a variety of impurities traceable to a great variety of causes. The character of the crude oil depends not only upon the kind and part of the vegetable (wood, nut, seed, etc.) and animal (fish, whale, etc.) used, but the quality of the raw material at the time of expressage or extraction (rusting, rotting, fermentation, sprouting, heating, etc.), the method followed, the care exercised in the process, and the conditions to which the oil is subjected prior to its refining. In many cases, in fact, we find metallic soaps present in the crude oil, which soaps have resulted from an interaction of decomposition products of the oil and the rendering vessels.

No universal method for refining animal and vegetable oils is known. Your forbearance will not be taxed, however, even were it profitable, in discussing all the various proposals for fitting these oils best to the several purposes experience and practice have shown them to be applicable. A number of processes have been proposed, patented, or kept secret during the last 125 years. Around the knowledge and power of the practical oil-refiner not a

little mystery still obtains. Each individual oil presents its own problem, and even the same oil by name, obtained under different conditions, involves judgment, based on the knowledge of the chemistry involved, to secure the best and most economical results. Furthermore, the use to which the oil is to be put must be considered; for example, one wants acid oil for some paints and neutral oils for foods.

Some four general methods for refining oils have been and are being worked in practice. They are:

1. Treatment with steam (plain or superheated) whereby some coagulation results and many odoriferous substances are driven off. This does not diminish the free fatty acid content of the oil so treated.

2. Treatment with variable amounts of concentrated sulphuric acid (Gower, 1792) under determined conditions of heat and agitation with or without air. The oil contains certain substances which, when flocculated by the acid and temperature, fall down and mechanically (a term used in several recognized authoritative books) carry down other impurities. This process does not diminish the acid content of the oil so treated.

3. Heating up under carefully-regulated temperature conditions with fullers' earth, bone-black, etc., and filtering. This process also yields an acid oil.

4. Adding caustic alkalies, or alkaline earths, of an amount and strength determined by laboratory experience (Barreswil, beginning nineteenth century), heating to the "break," settling and drawing off the oil, which floats upon the soap stock or "foots." This was supposed to give a neutral oil, but not until it had been washed several times with water.

Yet as late as last year a distinguished oil chemist, in a very interesting summary of the "Contributions of the Chemist to the Cotton-seed Oil Industry,"[1] said "the chemist . . . found that the quality of the oil followed the free fatty acid present." An empirical formula has been worked out to show this relationship to the free fatty acid. The rule is: Multiply the f. f. a. by 2 and add 4; that is, an oil showing 2 per cent. f. f. a. should give a shrinkage of 8 per cent. This is true only in a general way. I recently had a cotton-seed oil with 1.7 per cent. f. f. a., which

[1] *Journ. Ind. and Eng. Chem.*, 7 (1915), 277.

showed a shrinkage of 21 per cent. by the official method of the Cotton-seed Crushers' Association.

The writer quoted above further said "the chemist's greatest service to the industry has been in the refining of the oil . . ."

Wesson was here referring more especially to edible cotton-seed oil. In that connection, Lewkowitsch, the lamented Anglo-German specialist in oil chemistry and technology, has said:[2] "No chemically-treated oil or fat can be looked upon as a product fit for human consumption." I confess inability to comprehend this sharp distinction as to what is meant by a "chemical." Oxygen from a chromate is a chemical; oxygen of the air is not. Sulphuric acid is a chemical; caustic soda is not. It may be interjected here that certain statements transmitted by texts and sanctioned by law call for clarification and revision. No treatment of an oil or fat, which involves purification, rendering it palatable, agreeable to the sight, and avoids the introduction of constituents which may interfere with normal digestion should be forbidden. For fear of misunderstanding, it may be stated here that the method described below complies with all the most rigid laws of all nations and even the above-mentioned uneven discriminations.

An oil that is acid is unsatisfactory as a food. Acid oils corrode the vessels and generate objectionable gaseous products when used as burning fluids. Acid oils corrode the bearings when used as lubricants; so it is desirable to have neutral oils for many purposes. Yet a neutral oil does not "cut" into white lead, for example, so an acid oil is preferred as a paint vehicle; but Gardner has pointed out that the oil should not be too acid.

I have been more concerned with neutral oils and their production, so shall confine my remarks to preparation of that class of substances.

The present customary practice for refining vegetable oils referred to (the fourth mentioned above) depends upon neutralizing the free fatty acids in the crude oil usually by agitating the oil with an aqueous solution of an alkali, the strength and the amount having been previously determined by laboratory tests, agreed upon as a standard, and then heating the mixture during agitation to a suitable temperature until the oil "breaks." The mass is then allowed to stand until the "foots" settle to the bottom

[2] Vol. 2, p. 32, 3rd Edition.

of the kettle, when the supernatant oil is drawn off by means of a swivel siphon. According to the process of Chisholm, sodium silicate is added to facilitate the settling. Invariably some "dreg" floats on top of the oil. If this be very great its settling is sometimes facilitated by throwing salt on top of the oil in the kettle. The salt drags down some of the floating "dreg." In any event, the oil drawn off is clouded, perhaps on account of the presence of some dissolved soap or globulated moisture or suspended matter —all doubtless colloidal in nature. This oil is then "brightened" after drawing off by throwing in small amounts of fullers' earth, heating again, and passing through a filter-press. Sometimes, previous to this treatment with fullers' earth, the decanted oil is heated to 160° to 180° F. in a settling tank to cause the "foots" remaining in the oil to rise to the top, when it is skimmed off.

The time factor in settling (six to twelve hours) of the "foots" materially affects the completeness of the separation referred to above. Cocoanut oil sometimes requires forty-eight hours to settle. In any event, the "foots" is wet with oil. The "foots" also entrains oil. Consequently during the rush season the efficiency of yield of refined oil must be sacrificed for speed and quantity refined. In other words, the more speed in refining, the more loss of refined oil, whatever the analysis, upon which purchase and sale are based, may indicate.

A process which would reduce the amount of oil entrained in the "foots" to a minimum, thus increasing the yield of refined oil, and one which would not be dependent upon the slow subsidence of the "foots" (that is, admit of rapid separation with consequent increase in capacity of a refinery), therefore, seemed to me not only to be desirable, but, if secured, would approximate the highest efficiency one might hope for in such an industrial operation.

I have succeeded in working out such a process, and shall now proceed to describe the principles involved and at the same time demonstrate it to you as an analytical method. I have pleasure in exhibiting to you samples of the crude and refined (by my method) oils from a variety of sources.

The technical laboratory tests with batches of twelve to twenty pounds have been verified in the factory on a commercial scale. Some of the samples exhibited are from factory runs.

The aims to be accomplished are:

1. To reduce the amount of oil entrained in the " foots," thus increasing the yield of " whole oil."

2. To reduce the time of contact of the excess alkali (necessary for the " break " and to secure the best " color ") to the minimum.

3. A technological corollary calls for the utilization of any by-products.

It is to be assumed that all oils, good, bad, and indifferent, are to be treated. However, this may not be necessary, as in some cases only the good, and perhaps the indifferent, oils are refined under the old practice at some places. Certain foreign markets call for a highly-colored oil, so they do not present the problem of bleaching.

In my investigations, lasting through several years, I have taken various kinds of crude vegetable oils from various kinds of sources with various (extreme) conditions and refined them. In many cases I have been told that no attempt would ordinarily be made to refine a particular oil, as it should be sent to the soap-kettle, the corresponding price only being expected. Such oils would have represented much better values if they could have been refined by the usual practice. These oils in every case have yielded to my process, have been refined, and with a saving over the old processes. I may say, however, that China wood (tung) oil, castor oil, and aged linseed oil cannot be economically refined by the process. I wish also to repeat that I am referring to the production of neutral refined oils only.

If we can get the " foots " into such a condition that it may be filtered and then squeezed, we may reduce the amount of " whole oil " entrained.

If we can do this immediately after the " break " and while the oil is still hot, we shall be able to reduce the time the " whole oil " is exposed to the saponifying action of the excess alkali necessary to secure proper color, avoid the present practice of necessary " cleaning," and the second heating.

I have called your attention to the presence of bodies, which in general terms are called colloids, in oils. These colloids may or may not be colored; may or may not make the oil turbid. I have also shown that some colloids may be and are coagulated by heat, some by acids, some by alkalies, some by salts or electrolytes, and in time will settle out. Colloids that have been coagulated or lumped may be filtered out. Some coagulated colloids in their formation

adsorb coloring matter. The problem of economical filtration on the large scale necessary was one of great difficulty; in fact, so far as I am aware, it was unsolved previous to my investigation. Suitably-prepared cellulose fibre will adsorb some coloring matter. It will bring about an agglomeration of the material precipitated from oils by treating the oil with alkalies and heating, and it will bind the particles together so that they may lose their somewhat slimy character and then may be easily filtered away from the oil in which they were produced. Short-fibred "linters" or "delint" is a suitable form of cellulose for some oils.

Therefore I add cellulose, suitably prepared, along with the caustic to the oil to be refined. The "break" takes place normally on heating as in the ordinary process, but the precipitated mass is in such a physical condition that it may be separated from the oil immediately by filtration.

As mentioned above, some colloids, perhaps colored, are thrown down by salts, so in certain cases some salt (1 per cent. of sodium chloride) may be added. If there be a slight excess of water present, the sodium chloride serves also to "salt out" any soap in that water. The addition of salt, however, is not necessary in all cases.

I have also discovered that the tendency of the soaps formed by the caustic-alkali treatment to emulsify with the oil, or so to distribute themselves through the oil as to render their separation difficult, may be overcome by subjecting the oil, at a suitable stage of the treatment, to the action of an anhydrous salt which is capable of taking up water of crystallization, the perferred salt being dry sodium carbonate (soda ash), which, as is well known, is capable of taking up one, seven, or ten molecules of water of crystallization, according to temperature conditions. By such treatment the soaps which have already been formed by the treatment with caustic alkali, and which have become so incorporated with the oil as to be incapable of complete separation by ordinary filtration, are hardened or pectised, presumably by dehydration, and are so modified that they are readily separated by simple filtration. Sodium sulphate, which acts in the same way, may be used instead of soda ash.

The process is carried out by adding ordinarily 2 per cent. of prepared cellulose (less than 1 per cent. real cellulose) and a suitable amount of caustic soda (usually much stronger but

actually less in amount than is commonly used). The whole is thoroughly basted by mechanical means and then heated to 45° to 65° C. to produce the "break"; a determined amount of soda ash is added, after which it is filtered. At first some soap may pass through the filter-cloths. In that event, the first filtered oil may be run directly back into the refining kettle and pumped through the press until the oil is "bright." This usually occurs within a few minutes; in fact, the speed of filtration is directly dependent upon the speed of the pumps. This re-filtration also improves the color. This oil is neutral and can be deodorized and bleached, or both at once, or may be stored safely. If linters is used, ¼ to ½ per cent. of the dry cellulose is added.

These ideas are covered by four United States patents granted, Nos. 1,105,743, 1,105,744, 1,114,095, 1,130,698, and others applied for.

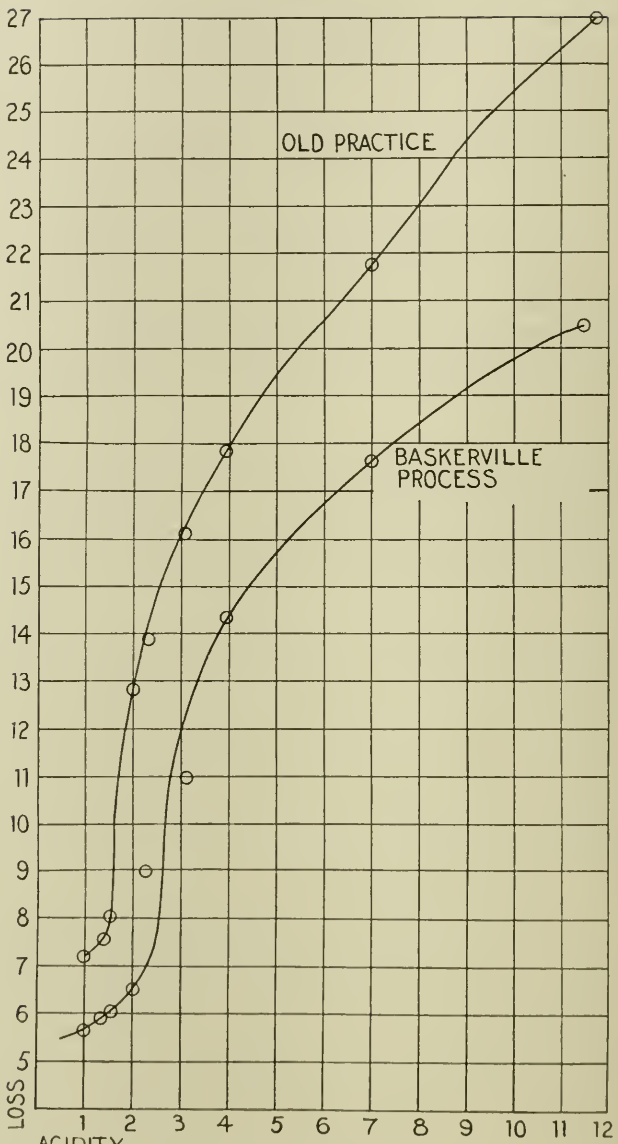
The danger of making a whole kettle into soap stock through failure of the refiner to be "on the job" is reduced to a minimum, as in several thousand trials this has not occurred, the trials being made by different people with various grades of oils of different character. In other words, the process is near "fool-proof." Any man of fair intelligence can operate the process, and the air of mystery surrounding the professional refiner is dissipated. The superintendent has a double check on the refinery by weighing the finished oil and cake. The daily reports when summed up should coincide with the annual inventory. I have known of cases where as much as 100,000 pounds of oil have failed to appear in the annual inventory, but were reported daily and had to be charged up to profit and loss at the end of the fiscal year when the operation was under the usual process.

The following curves have been prepared from a series of cotton-seed oils very variable in character (Fig. 1). The second chart (Fig. 2) shows the comparative losses with several other oils. They show the comparative losses by the normal present practice and my process.

I have also been able to secure a further 1 to 3 per cent. saving by subjecting the "cake" to hydraulic pressure. This extra saving is not shown in the charts.

The process is very rapid, the controlling factor being filter-press capacity. A study of plate filter-presses has indicated a preference for a centre-feed press making 1½- to 2-inch cakes.

FIG. 1.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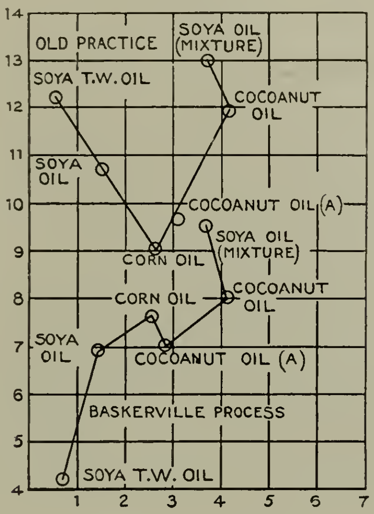
ACIDITY
OLD PRACTICE
BASKERVILLE
PROCESS

The filter-press problem in connection with the process is not one of filtering area, but cake capacity. Presses, as the Kelly or Sweetland, which are dumped mechanically, meet the conditions better than plate presses. A new Sweetland press recently devised for this process promises the best results. It is provided with bottom exits for the refined oil, and the under bivalve swings through an arc of 165 degrees. Monel metal filter-cloth makes the machine

Fig. 2.



practically permanent. By a slight increase in filter-press capacity the output of a refinery may be doubled or even tripled.

UTILIZATION OF BY-PRODUCT.

The cake may be converted directly into soap, the cellulose becoming very finely comminuted. It is partially mercerized, partly converted into a colloid, and some of it forms an unobjectionable filler for some grades of soap, especially soap powders.

The cake may be "cut" with acid directly. The cellulose settles quickly in the aqueous layer from the black grease, which latter may be drawn off ready for market or use. When the cake is to be "cut," in order to reduce the amount of acid necessary, I prefer to use salt cake in place of soda ash as the "agglomerator."

A solution of nitre cake, the process of Dr. Jeffrey Stewart, of Philadelphia, patent assigned to the duPont de Nemours Company.

for the recovery of oil from soap stock, can also be used in cutting the cake. In view of the high price of acid at present, this may serve as an economical method for making "black grease."

Printed instructions for the use of the method in practice or as analytical procedure will be supplied to any who will write for them.

SUMMARY.

A process has been worked out, based on scientific principles, for preparing neutral oils, which possesses the following advantages:

1. The actual refined oil obtained is from 1 to 10 per cent. more than now secured. Placed at a low average of 3 per cent., the process will save the cotton-seed oil industry in this country over $2,000,000 a year when prices are normal. The soja-bean oil industry, just developing in this country, can save 5 per cent. The peanut oil industry can save 6 per cent. The cocoanut oil industry can save from 3 to 5 per cent.

2. The process takes from one-tenth to one-third the time now necessary. Hence the capacity of the refinery is increased. This is of great importance during the rush season; in fact, its introduction will in economic efficiency perform the same rôle the tungsten filament lamp has played in the electric lighting industry, whereby the light production of a power station has been tripled.

3. The process gives a daily double check on the efficiency of the refinery.

4. The process is applicable to all grades of edible oils, which is not true with the common procedure.

5. Little new machinery is needed. The extra filter-press capacity called for will be more than paid for in the first year's profit.

6. The cost of chemicals is the same or less.

7. The by-product cake may be converted directly into a useful and commercial material.

THE COLLEGE OF THE CITY OF NEW YORK.

PORTLAND CEMENT.*

BY

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Portland cement may be defined as "the finely-pulverized product resulting from partial fusion of an intimate mixture of properly-proportioned argillaceous and calcareous materials."[1] When the fine powder is mixed with water a hard, stone-like mass is formed. The mortar thus obtained with Portland cement is far superior in strength and durability to any of the other various types of mortars commonly used in construction. This is due to the fact that Portland cement, which is the only cement formed by partial fusion of the raw materials, contains a compound known as tricalcic silicate, which is only formed at extremely high temperatures. The value of employing high temperatures in the manufacture of cement was discovered about one hundred years ago; it is only in recent years, however, that the process for the manufacture of Portland cement has been sufficiently developed so as to produce a uniform product on a large scale. Forty years ago its use was limited and it was manufactured only on a small scale; at the present time its use is so widespread that in 1915 it required over 90,000,000 barrels, costing over $125,000,000, to supply the demand in this country alone. This tremendous increase in production has been due to the increased use of Portland cement as a structural material, especially in concrete. The uses for concrete are many. It is used for the construction of sidewalks, roads, houses, dams, bridges, tunnels, forts, etc. In general, it may be said, therefore, that concrete is a substitute for stone. In some respects concrete is superior to stone as a building material, but under many conditions it is not so durable as the best building stone. One often sees a cement sidewalk which has disintegrated or hears of a concrete dam or bridge that is gradually going to pieces. There is reason to believe, however, that it may

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, March 2, 1916.

[1] Standard Specifications, Am. Soc. Test. Materials, etc.

be possible to produce a cement which will yield a concrete of much greater durability than the Portland cement now made. Indeed, as the demand for Portland cement has increased and as the requirements of engineers have called for material of better quality, the manufacturers have been able to meet these demands and to improve continuously the quality of their product. This continuous improvement has been brought about almost entirely by improvements in the mechanical appliances and methods of the industry, and owes very little to new ideas of how to make Portland cement, based on a knowledge of what the product really is. And, in view of this fact that such progress has been possible under such circumstances, it would seem not unreasonable to look forward to further improvement in cement, now that its constitution has been definitely ascertained.

We now know that Portland cement is made up of a number of chemical compounds, and that of these compounds there is but one which in itself possesses all the properties of a desirable Portland cement. This compound, tricalcic silicate, makes up only about 35 per cent. of an average Portland cement. It would appear, therefore, that one method of increasing the strength and durability of Portland cement would be to increase the percentage of tricalcic silicate.

The early investigations which ultimately led to the production of cement containing tricalcic silicate may be said to have started from the desire of engineers to obtain a satisfactory cement which would harden under water. In order to discover such a cement, two distinct modes of attack were employed: the one, representative of the first investigations in England, was to proceed by more or less "hit-and-miss" methods to the determination of the proper substances to be used and of the methods employed for the manufacture of an hydraulic cement; the other mode of attack, which originated in France, was to proceed in a systematic manner and to make use of the knowledge of the chemistry of the substances available for such a cement.

While it is not our present purpose to take up an extended discussion of the relative merits of these two types of cement investigation, it may be well to give a brief account of the most important early investigations of each type, taking up first the researches carried on in England and then those of M. Vicat in France.

The cement industry may be said to have started in 1756 from the researches of John Smeaton, an English engineer. Smeaton [2] had been employed by Parliament to build a lighthouse upon a group of partially-exposed rocks in the English Channel. Two wooden structures had previously been built and each had experienced a comparatively short life. When Smeaton attacked the problem, he determined to build a structure which would weather the fiercest storms of the channel. One of the greatest difficulties he had to overcome was the failure of ordinary lime mortar to harden under water. In order that his foundations be firm it was necessary that some mortar be found which would meet this difficulty. To this end he undertook a series of investigations of lime mortars, the result of which was the discovery that a clayey limestone, when burned, produced a mortar which would not only harden better in air than ordinary lime but would also harden under water. Such a clayey limestone Smeaton found in Cornwall, and he made hydraulic lime by burning this stone. This hydraulic lime, when mixed with pazzolana, a pumice-like material of volcanic origin, produced a satisfactory mortar which Smeaton used in the construction of the Eddystone lighthouse. This cement of Smeaton's, while it was undoubtedly an excellent structural material, has never been widely used, for the reason that pozzolana is found only in a few volcanic regions, notably Italy, where it was previously used in the making of the famous old Roman cements.

This circumstance, that pozzolana was not found in England, led to further investigations to determine the possibility of making a satisfactory water cement without this ingredient. As a result of these investigations various processes for the manufacture of artificial Roman cements were patented. These so-called cements were really hydraulic limes, similar to that prepared by Smeaton, though they were made by burning limestone containing a rather higher percentage of clay. It was from one of these hydraulic limes, patented in 1824 by Joseph Aspdin, an English bricklayer, that Portland cement derives its name. Aspdin took out a patent for the manufacture of an improved cement, which he called Portland cement from its resemblance in appearance after hardening to Portland stone, a famous English building stone.

[2] John Smeaton, "Narrative of the Building, etc., of the Eddystone Lighthouse," chap. 5, Book VI.

This cement was made by heating together an intimate mixture of limestone and clay to a temperature sufficient to expel the carbon dioxide. The process thus described is incapable of producing a cement such as is now known as Portland cement, the temperature of burning not being sufficiently high for the formation of *the* essential constituent, tricalcic silicate. It was not long, however, before this defect became obvious, the value of burning to a temperature of incipient fusion being discovered in 1825. While the superiority of the cements thus made by partial fusion of the raw materials was soon recognized, the knowledge of why fusion is essential has but recently been discovered. We now know that it is tricalcic silicate which imparts to Portland cement its most valuable properties, and that it requires extremely high temperatures in order that this compound be formed from limestone and clay. In spite of this lack of scientific knowledge during the early stages of the development of the Portland cement industry in England, the proper proportions of limestone and clay to be used were discovered by burning various mixtures and testing the physical properties of the cements thus obtained.

The first scientific knowledge of the chemistry of cements resulted from various investigations carried on in France. Of these early researches, the most important are undoubtedly those of M. Vicat, who undertook to straighten out the chaos of opinions and opposing facts regarding cements which existed at the time he started his work in 1812. Without taking up the exact nature of the chaotic conditions, it may be briefly stated that Vicat made an attempt to determine: the relation between the quality of hydraulic lime and cement and the chemical composition of the stone whence they are derived; the nature of the chemical compounds formed during burning; and the changes which take place when the cement is mixed with water and hardens.

While he did not entirely accomplish his purpose, Vicat did evolve some very interesting theories as to the hardening of calcareous mortar and cements.

The theory which Vicat first adopted was that a portion of the alumina and silica of the sand being acted upon by the lime caused the mortar to harden by chemical combination. It was not long, however, before he discovered that even in mortars eighteen months old the hydraulic lime is without chemical action on the granitic sands, and, further, that there is no integral transforma-

tion of this lime into its carbonate. These facts led him "to inquire into the influence of a mechanical agency of the particles, either considered as the result of a mere interlacement, or as to the proper cohesion of the lime, in comparison with its adherence to the quartz or calcareous substance embodied by it."[3] Discarding the hypothesis of a mere interlacement as untenable, he proceeded to inquire into the possibilities of a cement matrix possessing the faculty of: (1) hardening without perceptible shrinkage; (2) hardening with perceptible shrinkage; each case being considered when the adherence is stronger than the cohesion, and *vice versa*. Considering each of these possibilities with reference to the available data on the mortars then known, Vicat concludes that the mortars of hydraulic limes are the only ones which cannot be explained by such a theory of aggregates.

Referring to the hardening of eminently hydraulic mortars, he says:[4] "We are therefore compelled to have recourse to other considerations; and most of the difficulties will at once disappear, if we consent to admit, first, that the action of adherence is not confined to a superficial effect or to contact, but that to a certain extent it augments the cohesion peculiar to the matrix; second, that the limits of this extent are the more enlarged, the more favorable are the circumstances in which the mixture is placed, to a continuance of the molecular movement which takes place in the gangue; third, that lastly, the increase of cohesion in the matrix is inversely proportional to the distance of its particles from the aggregated body which acts the part of the nucleus." Applying this theory, Vicat says:[5] "Is it contrary to the principles of science to suppose that the film of lime which attaches itself in adhesion to the surface of a hard body becomes itself a hard substance in respect to the film next to it, and that one after another these films may finally adhere to one another by an attraction superadded to the cohesion natural to them? Doubtless no; such an action may be kept up for a very long continuance, especially when the moist condition of the matrix favors it."

"The very remarkable experiments of Mr. Petot, Engineer of Roads, on the relations which exist between the solubilities of hydraulic lime joined with sand, and the proportions of mixtures,

[3] Vicat on Mortars and Cements (Trans. Cap. J. T. Smith), 288, p. 126.

[4] *Loc. cit.*, 307, p. 132.

[5] *Loc. cit.*, 308, p. 133.

leaves no doubt of the influence exerted by the presence of the quartz upon the cohesion of the lime."

Referring to this statement, J. T. Smith, who translated the works of Vicat, says (p. 134): "This observation seems to be confirmed by the result of some of my own experiments, although they were undertaken with quite a different view. In endeavoring to account for the absence of carbonic acid in mortars of great age, and in searching for the neutralizing power which had supplied its place in part, in depriving lime of its caustic quality, etc. . . ." The only ingredient which could produce this effect was, according to Smith, silica, although he was unable to obtain any direct proofs on which to found the assertion "that silica exercises a neutralizing power with lime in the humid way." He was able to show, however, "that silica has a strong affinity for lime in circumstances which may frequently occur in hydraulic cements; these are, when it (silica) is in a minute state of division, especially if gelatinous; a fact which is shown by its communicating to it (lime) the property of hardening under water, under circumstances in which the induration cannot be occasioned by absorption of the fluid, as in the setting of plaster of Paris and some other cements."

To return again to the work of Vicat, he found that "Rich lime, when lodged amongst the grains of quartz of an ordinary mortar, retains in it its characteristic properties, which are, to be soluble to the last particle in water and to remain soft for a great number of years when excluded from contact with air (carbon dioxide). When mixed, however, in certain proportions with an energetic pozzolana in a pulverulent state, the lime disappears in a way, becomes insoluble, and communicates to the compound the faculty of hardening in a short time, either in water or in inclosures impermeable to the air. Now in what way does this lime thus change its nature?"[6] After refuting previous theory, to the effect that the hardening is due to carbonization of the lime, Vicat concludes (paragraph 314): "We persist in thinking, as we have always maintained till now, that the lime in cements of natural or artificial pozzolanas, etc., enters into chemical combination with these substances. Our opinion harmonizes with numerous facts set forth in the course of this work. These facts,

[6] *Loc. cit.*, 311, pp. 135–136.

it is true, cannot be looked upon as direct proofs, but we know that in matters of this kind direct proofs are extremely difficult and sometimes impossible to obtain; we know, moreover, that geometricians consider two straight lines to be equal, when they have proved that one can neither be smaller nor larger than the other."

In this manner Vicat ended his very valuable treatise on mortars and cements. The few scattered quotations from this work which are given here may appear to be rather incoherent, but they contain many ideas and suggestions which are extremely useful to those interested in the production of a Portland cement far superior to that now made. It is true that the cements which Vicat prepared and studied are inferior and have little resemblance to present-day Portland cement; even so, the fundamental theories of cement making which he advanced have not been refuted up to the present time and appear as applicable to Portland cement as to Vicat's hydraulic limes and cements.

These theories of cement making, which one must infer Vicat had in mind though he embodied them in no simple direct statement, are: (1) that the lime contained in cement mortars should be present in chemical combination with some material other than water; (2) that this other material should be silica, preferably in a finely-divided or gelatinous condition.

Later in this paper, after having presented our present knowledge of the constitution of Portland cement and of the chemistry of the hardening of mortar, an attempt will be made to show that Vicat's theories not only explain in a measure the essential active principle of the hardening of Portland cement mortar, but also indicate that it should be possible to produce a cement which will in turn produce a mortar of much greater strength and durability.

While Vicat, in France, was working out these theories as to the best cement practice, the English, with little or no theoretical knowledge (more by luck than otherwise), discovered a process for the production of an hydraulic cement far superior to any then produced in France. This discovery, of which a brief account has already been given, was, from one point of view, rather unfortunate, for the reason that it yielded a cement (Portland cement) so far superior to any previously known that apparently the idea became fixed—and to some extent still prevails—that there

is no possibility of producing a still better cement. It would appear that this minimized to some extent the recognition of the value of theoretical cement investigation, since but little of value was undertaken for some time after Vicat's investigations.

In spite of this fact, however, that but little has been known of the theoretical possibilities involved in the chemistry of the process, the many merely mechanical improvements have made possible the production of a better and more uniform product than was first made.

At first the English and later the German process produced cement which was the standard of quality; to-day, however, the best Portland cement is undoubtedly made in America. This has been brought about by improvements in the mechanical appliances of the industry which have been developed largely in this country and which, as we now know, have gradually increased the percentage of tricalcic silicate in cement by affording more favorable conditions for the formation of this compound.

Portland cement is ordinarily prepared by heating together a mixture of two raw materials, one composed largely of calcium carbonate, the other of aluminum silicates. The most typical materials answering to this description are limestone and clay, both of which occur in Nature in great quantities and in a number of varieties; other materials sometimes used are blast-furnace slag with limestone. Any combination of raw materials containing lime, alumina, and silica—the essential components—in the proper proportions may be used, however.

Briefly outlined, the method commonly used in America for the manufacture of Portland cement is as follows: The raw materials—namely, limestone and clay, or their equivalents—are crushed and dried, in order to insure satisfactory grinding and mixing; they are then mixed in the desired proportions, as indicated by previous chemical analysis, ground together until the whole of the material is reduced to very fine powder, and burned. The burning is carried out in a rotary kiln, the action of which is continuous, the raw material entering at one end and the cement clinker passing out at the other. These kilns are cylindrical, ranging from 60 to 150 feet in length and 5 to 8 feet in diameter, and are built up of steel plates lined with highly refractory material; they are supported in a slightly-inclined position by friction rollers and are slowly rotated. The fuel commonly used is

bituminous coal, which, after being thoroughly dried and powdered, is blown by compressed air into the lower end of the kiln, thus securing very thorough combustion. This arrangement insures the maintenance of a high temperature at the lower end of the kiln, so that the raw material passing down encounters a continually-increasing temperature. The changes taking place in the progress of the material through the kiln may be divided into three stages: in the first the material is thoroughly dried, in the second all organic matter is destroyed and the carbon dioxide of the calcium carbonate is expelled, while the third is the chemical reaction between the lime, alumina, and silica to form the clinker. The time of passage through the kiln is about one and one-half hours, and the final temperature is about 1425° C. The clinker, in the form of granules varying in size from that of a pea to that of a large marble, is a partially-fused mass of the chemical substances formed by the reactions occurring in the third stage; when ground to a fine powder, it constitutes the Portland cement of commerce. It is usual, however, to mix with the clinker, before it is ground, a small proportion of gypsum, the purpose of which is to regulate the time of setting of the cement when mixed with water.

It has just been stated that Portland cement clinker is the result of chemical combination of the three oxides, lime, alumina, silica: but beside these three—which are the essential components—two others, namely, magnesia and ferric oxide, always occur to some extent in commercial cement. The average of a large number of chemical analyses of American-made Portland cement is, according to Meade:[7]

CaO	62.0 per cent.	Fe_2O_3	2.5 per cent.
Al_2O_3	7.5 per cent.	MgO	2.5 per cent.
SiO_2	22.0 per cent.	SO_3	1.5 per cent.

From this it is evident that more than 90 per cent. of an average Portland cement consists of the three oxides, CaO, Al_2O_3, SiO_2; one would expect, therefore, that its properties are due mainly to the presence of the above three components, and that the relatively small admixture of the other oxides exerts at most a wholly secondary influence. Indeed, it has been shown that good Portland

[7] R. K. Meade, "Portland Cement," p. 30.

cement can be made from the three pure oxides, lime, alumina, and silica, in the proper proportions.

Now, ordinary chemical methods enable us to ascertain the aggregate proportion of each oxide present, but they yield us no information as to the manner in which these oxides are combined with one another—in other words, as to the substances which actually are present in the clinker and are responsible for its characteristic properties. The determination of this question is very important, for this reason; that, until we know what these substances actually are, we cannot hope to improve the quality in any desired direction, except by cut-and-try methods; and it is generally recognized that such empirical methods are much less certain, and take a vastly longer time to reach the goal, than methods based on a real knowledge of the factors in the problem. The determination of this question has been the object of a very large number of investigations; but the experimental basis of most of this work has been altogether insufficient to decide the several questions at issue. There has been in general a failure to realize the fact that a system so complicated as this can be unravelled only by proceeding systematically, using as a guide the principle known as the phase rule and establishing definite criteria for the recognition of the several substances which occur.

Cement clinker is a mixture of substances of very similar properties, and is, moreover, exceedingly fine grained, as a consequence of which it is a matter of some difficulty to make quantitative determinations of the constituents; but this difficulty can be surmounted by studying separately each of the presumable constituents of the clinker and determining definite values of certain properties which serve to characterize it and to distinguish it from other possible constituents. Accordingly the first problem is to isolate and determine all the possible compounds of lime, alumina, and silica which we may expect to find in Portland cement clinker, to establish their relations at high temperatures, and to ascertain their optical characteristics which constitute the most convenient and satisfactory criterion of the identity of the several substances.

These characteristic properties of the several solid substances, containing only CaO, Al_2O_3, SiO_2, which are likely to occur in Portland cement have been determined at the Geophysical Laboratory of the Carnegie Institution in Washington in the course of a systematic investigation of all compounds formed when any mix-

ture of these oxides is heated to a high temperature. In American-made Portland cements the relative proportions of these oxides vary only between comparatively narrow limits: CaO, 60 to 64; Al_2O_3, 5 to 9; SiO_2, 19 to 25; in other words, in considering this special problem we have to deal with a very restricted portion of the field of the whole system $CaO - Al_2O_3 - SiO_2$.

THE TERNARY SYSTEM $CaO-Al_2O_3-SiO_2$.

In order to work out this system completely it proved necessary to investigate about 1000 different mixtures of these three oxides and to make about 7000 heat treatments and microscopical examinations of the resultant products. Each such mixture, which was always made up of especially pure materials, was alternately fused and ground to a fine powder, the fusions being made in a platinum crucible to avoid contamination, in order to obtain a thoroughly-combined product. Each of these products was heated in an electric furnace, the temperature of which was carefully controlled and measured, until all changes had ceased, when it was quickly chilled; and the resultant material was subjected to a complete optical study. This procedure, which was carried out systematically, enables one to determine the crystalline phases present at temperatures ranging from that at which melting begins to that at which the charge is completely melted; and thus to ascertain the melting temperature and optical properties of all compounds of lime, alumina, and silica which form when any mixture of these three oxides is heated.

Before taking up the discussion of the application of the results thus obtained to the study of Portland cement clinker, a brief description, illustrated with photographs (Figs. 1 to 6) of the apparatus employed in this investigation, is given

Fig. 1 is a photograph of a battery of three Fletcher gas-blast furnaces in which the various mixtures of CaO, Al_2O_3, and SiO_2, contained in platinum crucibles, were fused. Three of the platinum crucibles used are shown in the foreground.

The crushing and grinding apparatus employed for the reduction of the fused material to a fine powder is shown in Fig. 2; the steel mortar and pestle being used for preliminary crushing; the battery of mechanical agate mortars for further crushing and grinding; and occasionally, when extremely fine powder was

FIG. 1.

Battery of three Fletcher gas-blast furnaces used for fusing mixtures of CaO, Al_2O_3, and SiO_2 in platinum crucibles.

FIG. 2.

Crushing and grinding apparatus for the reduction of clinker to a fine powder: (1) steel mortar and pestle; (2) battery of mechanical agate mortars; (3) porcelain ball mills.

desired, the material was subjected to the pulverizing action of the porcelain ball mill.

The general arrangement of the apparatus used for the isolation of the different crystalline compounds and for the determination of melting temperatures up to 1625° C. is shown in the photograph (Fig. 3). The essential features of this apparatus are the

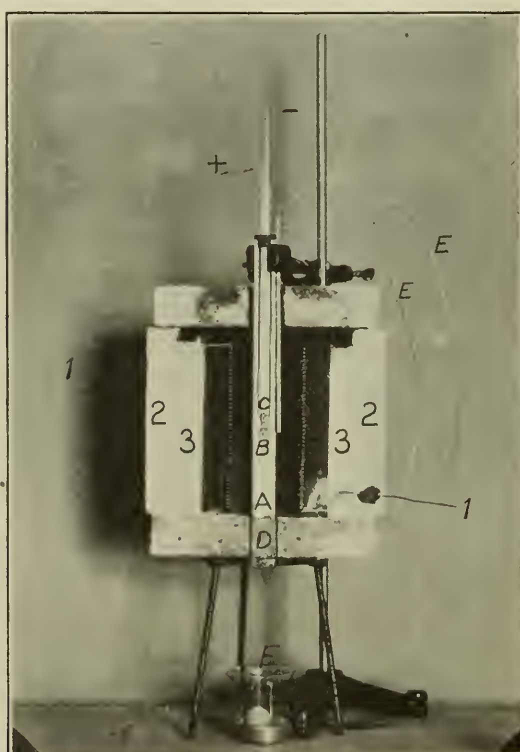
FIG. 3.

Photograph to show general arrangement of electric furnaces and temperature measuring device used for the determination of melting-points and for the isolation of the constituents of clinker: (1) platinum wire electric resistance furnaces; (2) Pt-Rh thermo-element; (3) electrical connection from thermo-element to galvanometer-potentiometer installation; (4) galvanometer; (5) potentiometer; (6) resistance for furnace temperature control.

platinum furnace and the temperature measuring device. The platinum furnace consists of a coil of platinum wire (wire 1.2 mm. diameter; coil 2½ inches diameter, 9 inches long, six turns to the inch) wound on the inside of a cylinder of impure magnesite which is insulated with MgO powder and a fire clay cylinder. Temperatures within the platinum furnace are measured with a platinum-rhodium thermo-element, in connection with a potentiometer and

galvanometer.[8] It is heated by the current from a storage battery (voltage 110, capacity 300 ampère hours), and the temperature within the furnace can be maintained constant (+ 2°) at 1550°

FIG. 4.



Cross-section of platinum quenching furnace: (1) platinum wire heating coil; (2) fire-clay shell of furnace; (3) highly refractory material for heat insulation; *A*, porcelain tube passing through centre of furnace; *E*, thermo-element; *B*, clinker wrapped in platinum foil; *C*, porcelain ring, suspended by fine platinum wire; + and −, heavy platinum wire leads; *D* removable plug; *F*, beaker of mercury.

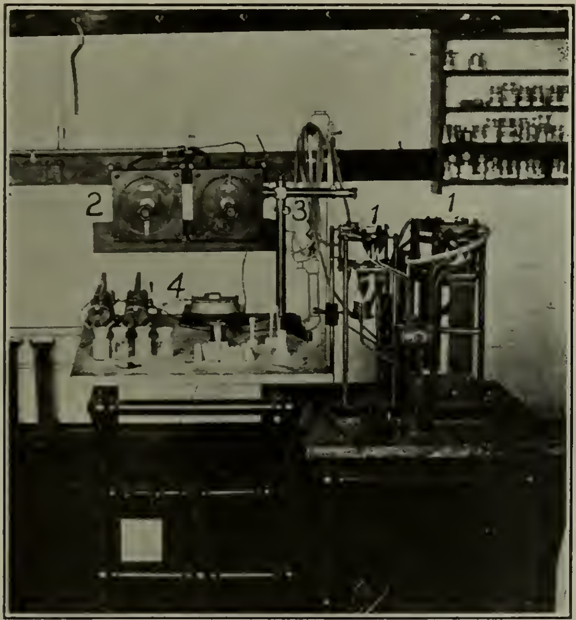
for a period of 12 hours; for lower temperatures the temperature can be maintained constant for much longer periods of time.

The photograph (Fig. 4) shows a vertical cross-section of a

[8] Walter P. White, "Potentiometer Installation, Especially for High-temperature and Thermo-electric Work," *Phys. Rev.*, xxv, 334–352 (1907).

platinum furnace fitted up with a quenching device. This device consists of a porcelain tube *A* passing through the furnace. On the outside of this tube the thermo-element *E* is fastened. The charge is contained in platinum foil *B*, suspended by a small porcelain ring from the fine platinum wire *C*. This wire is attached to two heavy platinum leads marked + and —. The tube is closed at the bottom by the removable plug *D*. *F* is a dish of

FIG. 5.



Photograph to show arrangement of iridium furnaces and optical pyrometer: (1) iridium furnace tubes within highly refractory shells; (2) electrical resistance for temperature control; (3) optical pyrometer; (4) ammeter for indicating temperature.

mercury. In operation the charge is brought to the desired temperature and held for a suitable length of time. The plug *D* is removed and a strong current passed through the wire *C*. The current fuses the wire, dropping the charge into the vessel *F*. The porcelain ring *C* prevents the wire of *B* from sticking to the suspending wire at *C*. The operation of the quenching device thus described enables one to quickly chill a small charge of material which has been heated to any temperature up to 1625° C.

For temperatures above 1625° C. no satisfactory quenching device or furnace has yet been devised for the study of mineral oxides. In such a furnace it is essential to maintain an oxidizing atmosphere and a fairly constant temperature which can be measured. Conditions approaching these requirements can be maintained in the iridium furnace, but no suitable refractory materials for the construction of a quenching device in this furnace are known. The iridium furnace consists of a straight iridium tube

FIG. 6.

Photograph to show arrangement of microscopes used for the study of constituents of clinker.

about 18 cm. long and 4 cm. in diameter, and is heated by a low-voltage alternating current. Temperatures within this furnace are measured with an optical pyrometer.[9] This furnace is used only for the determination of melting-points of substances which melt completely at a definite temperature within the range of

[9] Day, Shepherd and Wright, "Lime-Silica Series of Minerals," *Am. Jour. Sci.* (4), xxii, 286, 1906.

$1625^\circ - 2100^\circ$. A photograph to show the general arrangement of the iridium furnace, with device for temperature control and the optical pyrometer used for the measurement of temperature in this furnace, is given as Fig. 5.

Fig. 6 is a photograph showing the microscopes used for the optical study of fused mixtures after being quenched from various temperatures.

Having shown the general method of attack and the nature of the apparatus employed in this investigation of CaO, Al_2O_3, and SiO_2, let us now consider the results obtained.

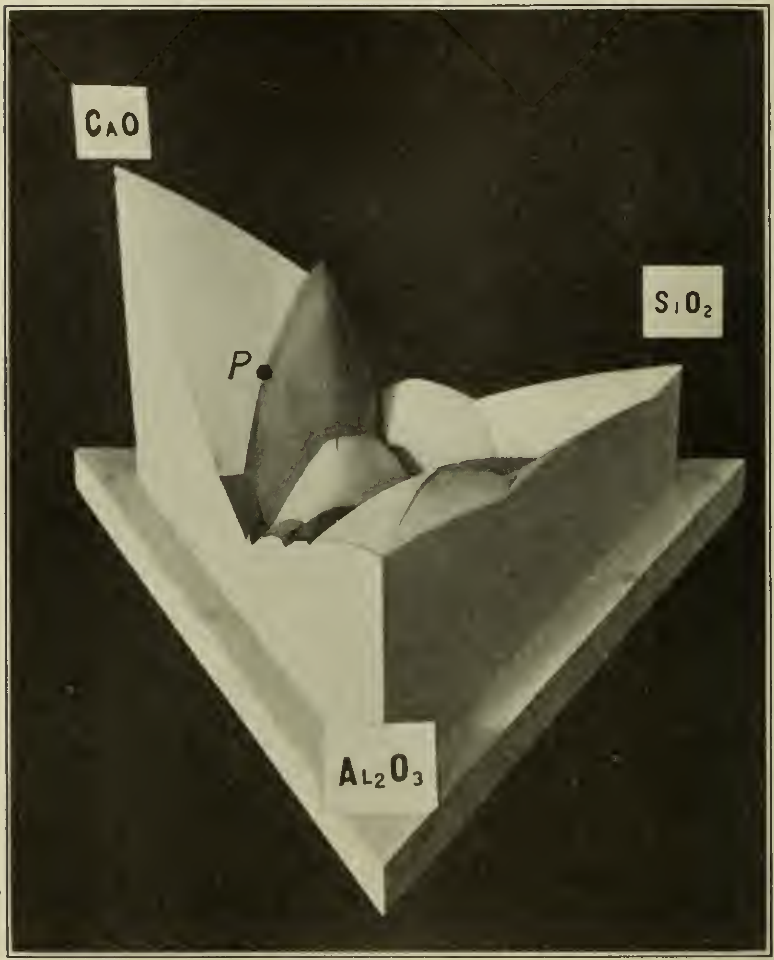
The data can be interpreted most readily if they are plotted in three dimensions; the concentration (composition) of each mixture is represented by a point within an equilateral triangle [10] on the horizontal plane, the magnitude of the corresponding temperature by the distance above this plane. It would lead us too far to go into details of the construction and properties of such a model; [11] suffice it to say that the series of surfaces thus described represent the melting temperatures of all products obtained when any mixture of the three oxides is heated progressively to higher and higher temperature. A photograph of such a model is reproduced in Fig. 7. As can be seen from the photograph, the model resembles a relief map of a mountainous region; each mountain peak is the melting-point of a pure component or of a pure compound; the mountain slopes represent the melting temperatures of a component or compound in ternary mixtures (each mountain slope in Fig. 7 is shaded in order to clearly define its boundaries); the points where the rivers in the valleys meet to form a lake are the lowest melting temperatures, known as eutectic points. This model, when interpreted with the aid of the principles underlying such equilibria, enables one to specify the order in which the several crystalline substances will appear when any melt composed entirely of lime, alumina, and silica is slowly cooled, and also to state what are the final products when any such melt has completely crystallized.

[10] In such a diagram, the pure components CaO, Al_2O_3, and SiO_2 are represented by the apices of the triangle; the binary systems CaO–Al_2O_3, CaO–SiO_2 and Al_2O_3–SiO_2 by the sides of the triangle, and ternary mixtures by points within the triangle.

[11] Those interested in the details of all this work are referred to previous papers, particularly Rankin and Wright, *Am. J. Sci.* (4), 39 (1915), 1, 79; and G. A. Rankin, *J. Ind. Eng. Chem.*, 7, 466 (1915).

Let us consider the crystalline substances which will separate from a melt composed only of these three oxides in the proportions

FIG. 7.

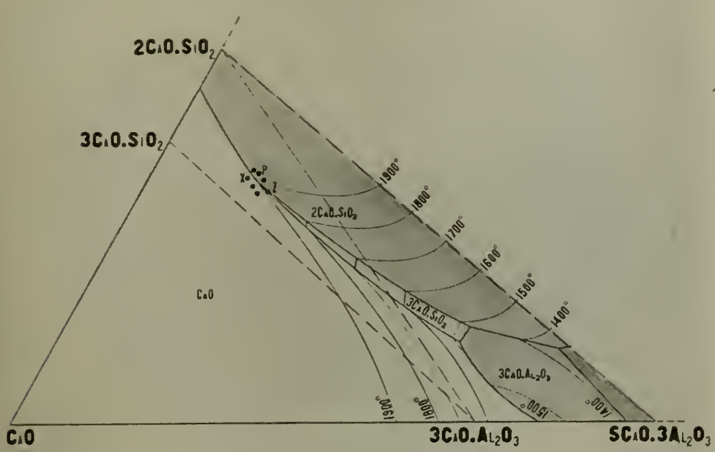


Photograph of solid model of concentration-temperature diagram of the ternary system $CaO-Al_2O_3-SiO_2$. Black dot P gives composition and melting temperature of pure Portland cement clinker.

such that they will produce a good Portland cement. For this purpose a diagram such as Fig. 8 is useful. This diagram is a projection on the horizontal plane of that portion of the solid

model necessary for our present purpose. The corresponding temperatures are here represented by isothermal lines, which are completely analogous to the contour lines on an ordinary map. The shaded areas correspond to the surfaces of Fig. 7. In this diagram the group of dots which represent mixtures of CaO, Al_2O_3, and SiO_2 from which Portland cement of good quality can be made correspond to the circle in solid model, Fig. 7. It will be seen that some of these dots represent points on the fusion

FIG. 8.



Projection of a portion of concentration-temperature solid model of system $CaO-Al_2O_3-SiO_2$, with isotherms. The dots represent mixtures of CaO, Al_2O_3, and SiO_2 from which Portland cement of good quality can be made.

surface of dicalcic silicate, others on the fusion surface of pure CaO, and still others, points on the fusion surface of tricalcic silicate.

If now a melt whose composition is represented by point P on the surface for dicalcic silicate is cooled, it is evident that this compound will crystallize at a temperature of about 1900° C. On further cooling dicalcic silicate will continue to crystallize alone until a temperature of about 1800° C. is reached, when tricalcic silicate will begin to crystallize. These two compounds,

dicalcic silicate and tricalcic silicate, will now crystallize together until, when the temperature of the cooling melt has reached 1455°, tricalcic aluminate appears. At this temperature the melt will crystallize completely, and the final product thus obtained will be made up of the compounds, dicalcic silicate, tricalcic silicate, and tricalcic aluminate.

The composition of the melt which when crystallized gives this product, it will be remembered, is that of point P on the melting surface of dicalcic silicate. If now a melt whose composition is represented by a point on the melting surface of CaO or tricalcic silicate is cooled, the same group of substances will be present in the final product. For example, if a melt of composition represented by point X is cooled, lime will be the first solid phase to crystallize. Subsequently, however, the lime will be resorbed and the final product obtained when melt X has completely crystallized will be made up of the same group of three compounds as result finally when melt P is cooled. Similarly, when a melt Z whose composition is represented by a point on the melting surface of tricalcic silicate is cooled, tricalcic silicate is the first solid to crystallize, but the final group of three, viz., tricalcic silicate, dicalcic silicate, and tricalcic aluminate, is the same.

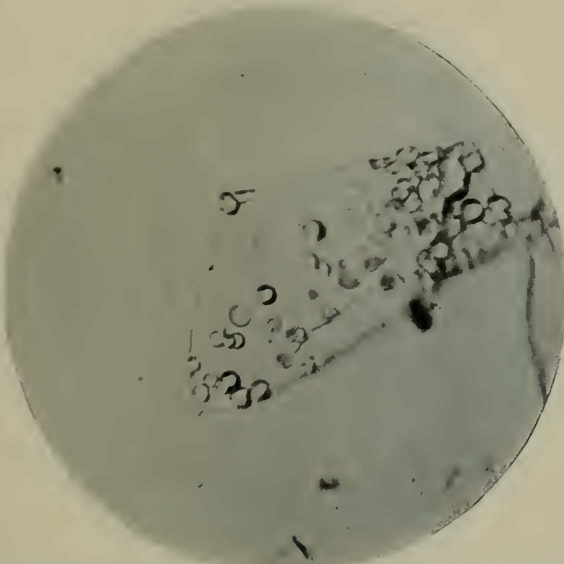
The reason why each of these three melts, P, X, and Z, should give the same products of crystallization—though the final proportions of three substances differ, of course, from one case to another—is evident if we consider their composition. It will be noticed that P, X, and Z represent compositions within the triangle formed by lines connecting the compositions of pure tricalcic silicate, pure dicalcic silicate, and pure tricalcic aluminate. Any melt whose composition is represented by a point in this triangle, when slowly cooled, will yield a final product made up of these three compounds; so that, while the order in which these compounds crystallize from the melts P, X, and Z respectively is different, the nature of the final product of crystallization is in each case necessarily the same.

Now the points P, X, and Z, in accordance with the statement on page 761, represent mixtures of CaO, Al_2O_3, and SiO_2 such that each will yield a good Portland cement when properly burned. We have now determined the compounds which will be formed when such mixtures are melted and slowly cooled. While Portland cement is not manufactured in this way, still the product

resulting from the crystallization of the completely-melted material is a good Portland cement, and the determination and identification of the constituents are more readily carried out.

In the actual manufacture of Portland cement, the necessary compounds are formed by burning at a temperature much below that required for complete melting. If, however, the cement clinker is not perfectly burned (the necessary compounds are not completely formed) there will be present, besides the three com-

FIG. 9.



Photomicrograph showing crystals of free lime imbedded in glass. Magnification, × 150.

pounds already mentioned, two others; namely, CaO and the compound $5CaO.Al_2O_3$.

The major constituents of Portland cement clinker made up only of the oxides CaO, Al_2O_3, and SiO_2 are, therefore, the three compounds $3CaO.SiO_2$, $2CaO.SiO_2$, and $3CaO.Al_2O_3$. The compound $5CaO.3Al_2O_3$ and CaO are minor constituents. Each of these compounds has optical properties peculiar to itself which serve to distinguish it from the rest. The several characteristic optical and crystallographical properties were obtained by a study of each compound by itself. These values are constants for the

individual compounds in all mixtures made up from pure CaO, Al_2O_3, and SiO_2; *i.e.*, the final products resulting when such mixtures are heated are present as individuals of constant optical properties and not as solid solutions. Photomicrographs, to show each of these constituents as isolated crystals, are given in Figs. 9 to 16. These crystals, which are shown here as they occur imbedded in fragments of glass, were thus obtained by the quench-

FIG. 10.*

Photomicrograph showing crystals of tricalic aluminate imbedded in a fragment of glass. Magnification, × 150.

*This photomicrograph of crystals of $3CaO.Al_2O_3$ shows an effect which is commonly observed in "quenchings" which contain a crystalline material which crystallizes very rapidly in a cooling melt. This effect, which is due to inability to prevent crystallization taking place during the quenching process, is shown here by the fine fringe surrounding the crystals which were present in the liquid (glass) before quenching.

ing method already described. It will be noticed that, except for the $3CaO.SiO_2$, the other constituents obtained in this way do not show any definite crystalline outline, but that they appear as more or less indistinct, irregularly-shaped grains in the fragments of glass. In spite of this, the fact that each of these grains is isolated in glass (surrounded by a medium of uniform optical character) enables one to determine its characteristic optical

properties. While it is not possible to show all of the optical characteristics of each constituent by photographs, it is possible to thus show certain of these characteristics.

Figs. 9, 10, and 11 represent crystals of lime, tricalcic aluminate, and the compound $5CaO.3Al_2O_3$, respectively, imbedded in fragments of glass. These three compounds are optically isotropic, so that it is not possible to show here the most characteristic distinguishing property of each of these compounds,

FIG. 11.

Photomicrograph showing crystals of the compound $5CaO.3Al_2O_3$ imbedded in a fragment of glass. Magnification, × 150.

namely, the value of its refractive index. Also, since they are isotropic, they are inactive toward polarized light, and so photomicrographs taken with the nicols crossed show simply a black field (Fig. 12).

Figs. 13 and 15 show crystals of dicalcic silicate and tricalcic silicate, respectively, imbedded in fragments of glass. Figs. 14 and 16 are the same, except that the photomicrographs were taken with the nicols crossed. This shows something as to the action of polarized light toward these compounds, dicalcic silicate and

tricalcic silicate, which are optically birefracting. It is not possible, however, to show photographically the exact difference in the birefringence of these two compounds, the birefringence of tricalcic silicate really being very weak as compared with that of dicalcic silicate.

These photomicrographs of the constituents of Portland cement, while they thus show something as to the optical nature of these compounds, are not sufficient for their certain identification, especially as they occur in fine-grained mixtures of the nature of Portland cement clinker. The identification of these compounds in such material requires more definite data, such as is contained in Table I.

Microscopical examination of commercial Portland cement clinker shows it to be made up largely (over 90 per cent.) of the three compounds, $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$. It would appear, therefore, that the value of Portland cement as a cementing material when mixed with water is largely due to one or more of these compounds. Before taking up the cementing value of each of these compounds, however, let us consider their formation when Portland cement is burned.

For this purpose let us follow the reactions which take place when a mixture whose composition is CaO (as $CaCO_3$) 68.4 per cent., Al_2O_3 8.0 per cent., and SiO_2 23.6 per cent. is slowly heated. This mixture made up only of the pure oxides lime, alumina, and silica, when properly burned, will produce a good Portland cement. When such a mixture is heated the first change is the evolution of the CO_2; the lime then unites with the other components to form the compounds $5CaO.3Al_2O_3$ and $2CaO.SiO_2$ (both of which form readily), probably in the order named, since the former has a lower melting-point than the latter; subsequently these two compounds unite in part with more lime, and the compounds $3CaO.Al_2O_3$ and $3CaO.SiO_2$ appear. This formation of the last two compounds—a process which goes on very slowly in mixtures of their own composition—is materially facilitated by the circumstance that in the ternary mixtures a portion of the charge has already melted and promotes reaction by acting as a flux or solvent. The temperature at which this flux first appears is 1335° C., the eutectic temperature for the three compounds $2CaO.SiO_2$, $5CaO.3Al_2O_3$, and $3CaO.Al_2O_3$. As the temperature of burning gradually rises above 1335° the relative amount of flux increases

TABLE I.

*Optical-Crystallographical Properties of the Compounds Present in Portland Cement Clinker.**

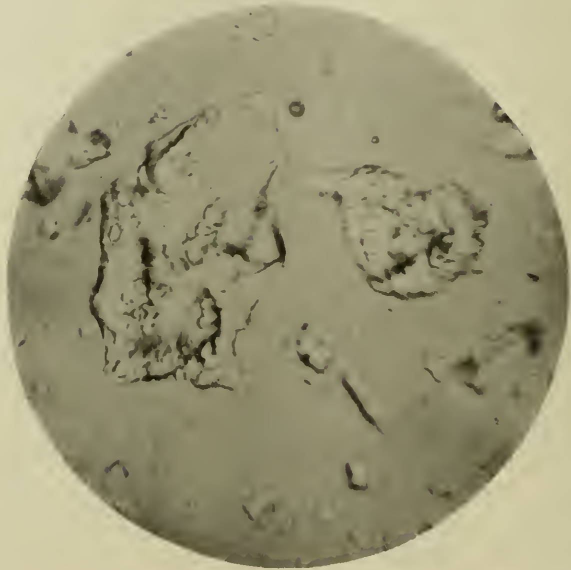
Composition	Crystal system	Crystal habit	Cleavage	Hardness	Elongation	Optical orientation	α	β	γ	Optical character	Optic axial angle	Remarks
CaO	isometric	unmodified cubes	perfect (100)	3–4	..	....	....	....	1.83	..	.....	Crystals often show optical anomalies.
γ-$2CaO.SiO_2$	probably monoclinic	prismatic	g (001) g (100)	... ...	γ α	$b=\beta$ $c:\gamma=3°(?)$	1.642	1.645	1.654	−	$2E=52°$	Obtainable only as fine powder. Plane of optic axes normal to cleavage direction.
β-$2CaO.SiO_2$	orthorhombic or monoclinic	irreg. grains prisms	poor	5–6	...	....	1.717		1.735	+	large	Plane of optic axes parallel to elongation.
α-$2CaO.SiO_2$	monoclinic or triclinic	irregular grains		5–6	...	$c:\alpha'=18°$	1.715	1.720	1.737	+	large	Intricate polysynthetic twinning is characteristic of this form.
β'-$2CaO.SiO_2$	....	equant gr.		...	...	....	....	....	1.715	+	small or uniaxial (?)	Birefringence very weak.
$3CaO.SiO_2$	monoclinic (?)	equant grains	....	...	...	$c=\gamma$	....	....	1.715	−	small or uniaxial	Birefringence very weak. Twinning lamellæ not uncommon.
$3CaO.Al_2O_3$	isometric	equant grains	p (111) or p (110)	6	...	....	....	....	1.710		....	Occasionally gray interference colors appear as result of strain.
$5CaO.3Al_2O_3$ (stable)	isometric	equant grains	fibers	5	...	....	....	....	1.608		....	Stable form.
$5CaO.3Al_2O_3$ (unstable)	probably orthorhombic	fibers prisms	p. prismatic	5	α	....	1.687		1.692	− (?)	large	Plane of optic axes parallel with fiber elongation.

* This table is a portion of that giving optical properties of all compounds of CaO, Al_3O_2 and SiO_2 as determined by F. E. Wright and published in *Am. Jour. Sci.*, [4] 39 (1915), 74–75.

FIG. 12.

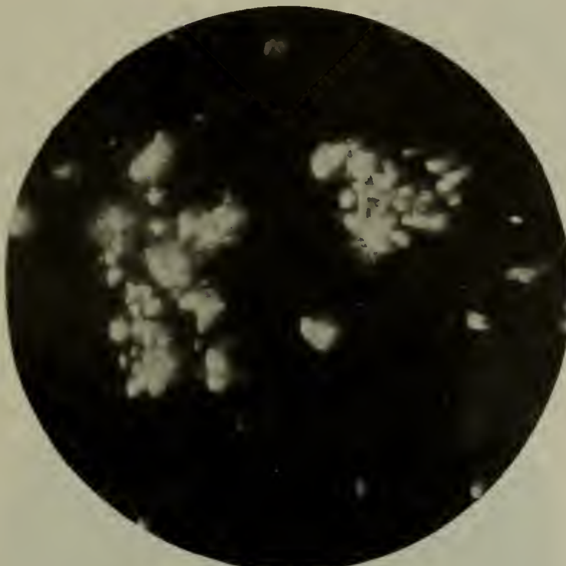
Photomicrograph, with nicols crossed, of either lime, tricalcic silicate, or $5CaO.3Al_2O_3$ imbedded in glass.

FIG. 13.



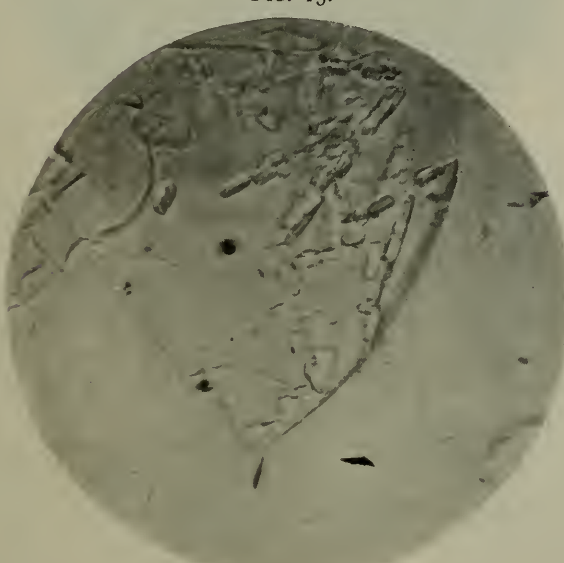
Photomicrograph showing crystals of dicalcic silicate imbedded in fragments of glass. Magnification, × 150.

FIG. 14.



Photomicrograph taken with crossed nicols, showing crystals of dicalcic silicate imbedded in fragments of glass. Magnification, × 150.

FIG. 15.



Photomicrograph showing crystals of tricalcic silicate imbedded in a fragment of glass. Magnification, × 150.

and the rate of formation of $3CaO.Al_2O_3$ and $3CaO.SiO_2$ increases correspondingly. At a temperature somewhat above 1335° the compound $5CaO.3Al_2O_3$ will have completely melted in the flux and the formation of $3CaO.Al_2O_3$ is complete. The substances present as crystals at this stage are $3CaO.SiO_2$, $3CaO.Al_2O_3$, $2CaO.SiO_2$, and free CaO. Of these the $3CaO.SiO_2$ is rapidly *increasing* in amount, due to combination of $2CaO.SiO_2$ with CaO, while the amounts of solid $2CaO.SiO_2$, CaO, and

FIG. 16.

Photomicrograph taken with crossed nicols, showing crystals of tricalcic silicate imbedded in a fragment of glass. Magnification, × 150.

$3CaO.Al_2O_3$ are all decreasing, the $2CaO.SiO_2$ partially by combination with CaO and partially by dissolving along with $3CaO.Al_2O_3$ in the flux. As the temperature is raised still further the amount of flux (liquid) increases and the rate of combination of $CaO.SiO_2$ to form $3CaO.SiO$ increases. But it is not necessary to raise the temperature until the charge is completely melted, as normal cement clinker is obtained at temperatures much below complete melting; in other words, the necessary reactions will go to completion below the temperature required for complete melting. The rapidity with which the reactions go to completion is

governed by the temperature and by the amount of the flux formed at that temperature. The requisite amount of flux, in turn, depends upon the fineness of the raw materials, since the finer these materials are ground the more readily the components will combine. For finely-ground raw materials of the above composition, composed only of CaO, Al_2O_3, and SiO_2, a temperature of about 1650° C. is required for burning. At this temperature the clinker would be about 30 per cent. melted and 70 per cent. solid crystalline material, a proportion of flux which would admit of the necessary reactions going to completion in a reasonable time. The charge will always completely crystallize on cooling; the percentage composition (based on actual data) of the clinker thus obtained would be approximately $3CaO.SiO_2$ 45 per cent., $2CaO.SiO_2$ 35 per cent., and $3CaO.Al_2O_3$ 20 per cent. The melting temperature of the flux necessary for the production of the clinker is materially lowered by the presence of small amounts of impurities; that the small amounts of Fe_2O_3, MgO, etc., in commercial cement actually have this effect is shown by the fact that the temperature required for burning is about 1425° C.

In the foregoing discussion we have followed to completion the course of the reactions which take place when cement clinker composed of pure CaO, Al_2O_3, and SiO_2 is burned; in other words, we have shown the formation of the compounds during the burning of mixtures of these three oxides in the proper proportions for cement clinker, and stated what compounds will be present in the final product if the burning is continued long enough and at a sufficiently high temperature.

The foregoing data, presented in a more concise manner, are given in Table II, which gives the constituents of Portland cement present between rather definite temperature intervals during the burning of this clinker. This table requires no special discussion. It may be well to mention, however, that, while free CaO is present at 1450° C., it will be entirely combined when the temperature reaches 1650° C.

TABLE II.

Formation of Constituents of Portland Cement During the Burning of the Clinker Composed Only of CaO, Al_2O_3, SiO_2.

Raw mix	1000° C.	1000°–1335°	1335°–1450°	1450°–1650°	Cool clinker
CaO (as $CaCO_3$)	CaO	CaO	CaO	CaO	$2CaO.SiO_2$
Al_2O_3	Al_2O_3	$5CaO.3Al_2O_3$	$3CaO.Al_2O_3$	$2CaO.SiO_2$	$3CaO.SiO_2$
SiO_2	SiO_2	$2CaO.SiO_2$	$2CaO.SiO_2$	$3CaO.SiO_2$	$3CaO.Al_2O_3$
		$3CaO.Al_2O_3$	$3CaO.SiO_2$	Flux	
			Flux		

The description and table, showing the essential reactions which take place when cement made up only of CaO, Al_2O_3, and SiO_2 is burned applies equally well to commercial Portland cement. In commercial cements, however, there are always present small amounts of Fe_2O_3, MgO, alkalies, etc. These minor components, which total less than 10 per cent., have but little effect on the major constituents of the clinker. During the burning of cement clinker, however, these minor components play an important part, since their presence insures the formation of a flux at a much lower temperature, and thereby materially promotes the combination of CaO with Al_2O_3 and SiO_2.

In order to afford a comparison of the chemical compositions, the temperature required for burning, and the final products obtained for different types of Portland cement, the necessary data have been collated in Table III. The examples given in this table are based on the average for a large number of analyses of each of three types of Portland cement, viz., pure cement, made only of CaO, Al_2O_3, and SiO_2; commercial white cement; and the more common gray variety of Portland cement.

TABLE III.

*Compositions and Burning Temperatures of Various Portland Cements.**

Portland cements	Percentage composition of clinker Actual components			Burning temperature °C.	Constituents of resulting cements	
Pure (P)	CaO	68.4	100.0	1650	$2CaO.SiO_2$	
	Al_2O_3	8.0			$3CaO.SiO_2$	
	SiO_2	23.6			$3CaO.Al_2O_3$	
White (A)	CaO	66.2	97.6	1525	$2CaO.SiO_2$	Small amount of CaO
	Al_2O_3	6.4			$3CaO.SiO_2$	
	SiO_2	25.0			$3CaO.Al_2O_3$	
	MgO, Fe_2O_3, Na_2O and K_2O		2.4			
Gray (B)	CaO	63.2	93.3	1425	$3CaO.SiO_2$	Small amounts of $CaO.3Al_2O_3$ CaO and ferrites
	Al_2O_3	7.7			$3CaO.SiO_2$	
	SiO_2	22.4			$3CaO.Al_2O_3$	
	MgO, Fe_2O_3, Na_2O, K_2O and SO_3		6.7			

* The data given in this table are based largely on the work of this laboratory. The analyses of commercial clinkers are from publications from the Bureau of Standards and from "Portland Cement," by R. K. Meade. The temperatures of burning and the constituents given are based both on our work and that of the Bureau of Standards.

If the raw material for pure cement is perfectly burned at a temperature of 1650°, the clinker obtained will consist of the three compounds — dicalcic silicate, tricalcic silicate, and tricalcic aluminate. The example of a pure cement given in Table III has the chemical composition 68.4 per cent. lime, 8.0 per cent. alumina, and 23.6 per cent. silica. The raw material for white commercial

cement, when burned at a temperature of 1525°, will produce a clinker which consists largely of the same three compounds found in pure clinker, except for a small amount of free lime. The average chemical composition of this type of cement as given in the table is 66.2 per cent. lime, 6.4 per cent. alumina, 25 per cent. silica, and 2.4 per cent. magnesia, iron oxide, and alkali. The clinker obtained on burning the raw material for commercial gray cement at 1425° will consist largely of the same three compounds found in the other two types of clinker, except for small amounts of free lime, the compound $5CaO.3Al_2O_3$, and iron oxide as ferrites. The composition of this clinker is 63.2 per cent. lime, 7.7 per cent. alumina, 22.4 per cent. silica, 6.7 per cent. MgO, Fe_2O_3, alkali, and SO_3.

The similarity of these three types of cement clinkers is not surprising if we consider their chemical compositions, the content of lime, alumina, and silica of each type being over 90 per cent. We should expect, therefore, and it has been found experimentally to be true, that these three types of cement clinker are made up largely of the same constituents, tricalcic silicate, dicalcic silicate, and tricalcic aluminate, all compounds of the three major components of cement.

Having shown that the components of Portland cement are CaO, Al_2O_3, and SiO_2, and that the constituent substances are definite compounds of these oxides, let us consider the percentage of these compounds in the clinker. For example, let us take the average gray cement whose chemical composition has been given in Table III. If the clinker for this cement has been perfectly burned, it will consist of about 36 per cent. $3CaO.SiO_2$, 33 per cent. $2CaO.SiO_2$, 21 per cent. $3CaO.Al_2O_3$, and 10 per cent. of the minor constituents.

In the actual manufacture of Portland cement, however, the clinker is not always perfectly burned; that is, the raw materials are not always ground fine enough or heated to a sufficiently high temperature so that the chemical reactions are completed. The proportions of the constituents in commercial cement will then be somewhat different from those given. With our present knowledge of the nature of the chemical reactions, however, it is possible to state which of the constituents will not be completely formed. It will be remembered that, in the discussion of these chemical reactions, it was shown that $3CaO.SiO_2$ is the last constituent to

form completely, and that this compound is formed by combination of CaO with the compound $2CaO.SiO_2$. It is evident, therefore, that when commercial clinker is not perfectly burned there is less $3CaO.SiO_2$ and more $2CaO.SiO_2$,[12] and CaO will be present as an individual constituent. In the example given there will be less than 36 per cent. $3CaO.SiO_2$, more than 33 per cent. $2CaO.SiO_2$, and there will be a certain percentage of free CaO. The exact percentages will, of course, depend upon how near to completion the reaction, $CaO + 2CaO.SiO_2 = 3CaO.SiO_2$, has been carried.

That the manufacture of good Portland cement necessitates that this reaction be carried practically to completion is evident if we consider certain facts in regard to the influence of lime on the physical properties of Portland cement. Practical experience has shown that cements containing much free lime are unsound, and that concrete made from them will in time disintegrate. This is due to the expansion of free or uncombined lime when it reacts with water to form calcium hydrate. If, however, the lime in cements is all combined, they are sound and of good strength. The importance of the reaction $CaO + 2CaO.SiO_2 = 3CaO.SiO_2$ is, therefore, apparent, since this reaction must go practically to completion in order that a sound cement may be produced. It has long been recognized that anything which will promote the combination of lime during burning will promote soundness in cement, and that the greater the percentage of combined lime the greater the strength of the cement.

The average lime content of cement to-day is about 62.5 per cent., which is largely combined as $3CaO.SiO_2$, $2CaO.SiO_2$, and $3CaO.Al_2O_3$. If the percentage of CaO were increased it would tend to combine with the $2CaO.SiO_2$ to form more $3CaO.SiO_2$, and would so combine if the time of burning were long enough and the temperature sufficiently high. Since practical experience has

[12] The "dusting," commonly observed in under-burned clinker when cooled, is due to the 10 per cent. expansion which accompanies the change of β $2CaO.SiO_2$ (stable at the clinkering temperature) to γ $2CaO.SiO_2$, the crystalline form of dicalcic silicate stable at temperatures below 600° C. This dusting ordinarily takes place only when the clinker contains a very high percentage of β $2CaO.SiO_2$, and does not take place when the clinker has been well burned. This β form of dicalcic silicate is, however, always present in a considerable quantity in well-burned clinker, so that the dicalcic silicate in cement clinker when cooled is in a state of unstable equilibrium.

shown that increased percentage of lime increases both the percentage of $3CaO.SiO_2$ and the strength of cements, it may be inferred that the strength of cements is largely due to the compound $3CaO.SiO_2$. If this is true, it is desirable that Portland cement should contain as high a percentage of this compound as is possible. An average Portland cement contains about 30 to 35 per cent. of this constituent. That Portland cement contains such a small amount of $3CaO.SiO_2$ is due partly to the fact that this constituent is formed with great difficulty and also to the fact that about 35 per cent. is the maximum yield which could be obtained from raw materials having the same CaO, Al_2O_3, and SiO_2 composition as is now used.

Before taking up, however, a discussion of the probable value of $3CaO.SiO_2$ as a cementing material and the possibility of increasing its percentage in Portland cement, let us consider what is known as to the cementing value of the constituents of Portland cement, taking up first the changes which take place when Portland cement is mixed with water and hardens.

When Portland cement is finely pulverized and mixed with water, a hard mass is formed by chemical action between the water and the constituents of the cement. The first change undergone by the cement mortar in passing from a plastic to a solid state is called "setting," which requires not over a few hours. After the mortar has set there is a gradual increase in the strength of the mass, and the cement is said to "harden." It sometimes requires a year's time for a cement to acquire its full strength.

While there is still much to be learned as to the chemistry of the hardening of Portland cement, sufficient data on the hydration of the individual major constituents have been obtained to enable us to account for this gradual hardening and increase in strength and to indicate the relative value of these constituents as cementing materials.

Let us now consider the hydration of the three major constituents, $3CaO.Al_2O_3$, $3CaO.SiO_2$, and $2CaO.SiO_2$, in the order named. When pure $3CaO.Al_2O_3$ is mixed with water an amorphous hydrated material is first formed. This material sets and hardens very rapidly. The compound $3CaO.SiO_2$, when mixed with water, also sets and hardens rather rapidly. In the case of this compound, as in the case for $3CaO.Al_2O_3$, the setting and hardening are due to the formation of an amorphous hydrated

material on the individual grains, which are thus cemented together. The extent of the hydration or the percentage of amorphous material which each grain will yield depends upon the percentage of water used and the time. With a given percentage of water the amount of amorphous material formed from the compound $3CaO.Al_2O_3$ in a given time is much greater than for the compound $3CaO.SiO_2$; that is, the compound $3CaO.Al_2O_3$ reacts with water much more rapidly than the $3CaO.SiO_2$. The compound $2CaO.SiO_2$ reacts very slowly with water, and it is only after a long period of time that sufficient amorphous hydrated material is formed to cement together the grains of this compound and so form a hard mass.

The amorphous hydrated material formed by the action of water on the constituents of cement does in time, no doubt, crystallize to some extent. From the data available it would appear that the crystals formed are calcium hydrate and some crystalline hydrate derived from $3CaO.Al_2O_3$. Apparently no crystalline hydrate of the calcium silicates is formed.

From this brief description of the action of water on the constituents of Portland cement it will be seen that the setting and hardening of Portland cement involve the formation of an amorphous hydrated material which subsequently partially crystallizes; that the initial set is probably due to the hydration of $3CaO.Al_2O_3$; that the hardness and cohesive strength at first are due to the cementing action of the amorphous material produced by the hydration of this aluminate and of the $3CaO.SiO_2$; and that the gradual increase in strength is due to further hydration of these two compounds, together with the hydration of the $2CaO.SiO_2$.

Of the three compounds which thus take part in the setting and hardening of Portland cement, the $3CaO.SiO_2$ appears the best cementing constituent; that is, this compound is the only one of the three which when mixed with water will set and harden within a reasonable time to form a mass which in hardness and strength is comparable to Portland cement. The compound $2CaO.SiO_2$ requires too long a time to set and harden in order to be in itself a valuable cementing material. The compound $3CaO.Al_2O_3$, while it sets and hardens rapidly, is rather soluble in water and is not particularly durable or strong.

From this it would appear that the compound tricalcic silicate

is *the* essential constituent of Portland cement; consequently the higher its percentage the better the cement. Before discussing the nature of an investigation which might lead to the production of a cement containing a high percentage of this compound, however, let us briefly reconsider the theories of Vicat in order to show the similarity between what appears to have been the ideal cement of his mind and tricalcic silicate.

Vicat, it will be remembered, seemed to believe that the lime in cement mortar should be in a state of chemical combination, and that it were best that it should be so combined with gelatinous silica.

When tricalcic silicate is mixed with water to form a mortar a gelatinous material is formed which is composed of hydrous lime and silica. Whether the lime and silica continue to be chemically combined or whether the gelatinous material is colloidal is still a matter of some uncertainty, although it would appear that this material is colloidal.

The similarity between Vicat's theoretical cement and tricalcic silicate is thus apparent.

The basis for Vicat's theoretical reasoning was undoubtedly derived from his observations on the action of hydrated lime when ground with water and pozzolana, a material which contains over 40 per cent. silica, with smaller percentages of Al_2O_3, MgO, Fe_2O_3, and alkalies. This mixture, commonly known as Roman cement mortar, it would now appear, sets and hardens in much the same manner as tricalcic silicate; in the case of Roman cement the formation of the gelatinous material, which subsequently hardens, being due to the action of lime water on the pozzolana. This action, however, is exceedingly slow, and it requires a much longer time for the completion of the hardening in Roman cement mortar than in mortar containing tricalcic silicate. This is undoubtedly due to the nature of the chemical combinations of silica in pozzolana, which react with water much less readily to form gelatinous silica than is the case of the silica combined in tricalcic silicate. This circumstance, that gelatinous silica is released with such readiness when tricalcic silicate is mixed with water, is probably the reason why this compound is such a valuable cementing material. Without discussing at length the nature of the cementing value of gelatinous silica, it may be well to state that it seems probable that certain of the toughest sandstones

(ideal concrete structures) are made up of grains of sand originally cemented together with gelatinous silica which was gradually deposited from solution on to the grains of sand and subsequently hardened.

This foregoing discussion, which tends to prove that gelatinous silica is the most essential constituent of a cement mortar, is somewhat speculative. That such speculation is desirable is due to the fact that by formulating advance theories as to the probable outcome of an investigation one may sooner attain the end. It is essential, however, that theory and established fact be not confused.

With this in mind, let us now consider certain possibilities which might increase the percentage of gelatinous silica in cement mortars. We know at the start in such an investigation that tricalcic silicate is probably the only compound containing silica in combination in such a manner that it is *readily* released to form a thin coating of gelatinous silica when mixed with water to form a mortar. Therefore, until some other compound is discovered in which the silica is combined in such a way that it is more readily available in the gelatinous state, the best way to increase its percentage in cement mortars is to increase the percentage of tricalcic silicate in cement clinker. Unfortunately this is difficult, although there are several very interesting possibilities.

Pure tricalcic silicate is formed by combination of lime and silica only with the greatest difficulty, the temperature of burning required, 1700° C., being too high for industrial practice. In order that this compound form readily and at a sufficiently low temperature so as to become a commercial possibility, it is necessary that some substance or substances other than lime and silica be present during the burning; these substances to be of such a nature that a low-melting, rather fluid flux is formed, so as to facilitate the combination of lime and silica to form tricalcic silicate. At present this flux is to a large extent furnished by the low-melting calcium aluminates in the clinker.

In the discussion of the constitution of Portland cement we have shown that an average Portland cement contains about 30 to 35 per cent. tricalcic silicate, a proportion which closely approaches the maximum possible yield with the present percentage of flux; in other words, if the components are in the proportions of an average Portland cement. It has also been shown that an

increase in the lime content of an average cement will increase the percentage of $3CaO.SiO_2$ if the conditions of burning are such that the reaction $CaO + 2CaO.SiO_2 = 3CaO.SiO_2$ goes to completion. This, however, necessitates finer grinding of the raw materials, as well as burning for a longer time and at an increased temperature, factors which materially affect the cost of production. Now the data discussed above were obtained by applying the results obtained by an investigation of the equilibrium relations found to exist in the system $CaO - Al_2O_3 - SiO_2$ to the actual manufacture of Portland cement; but this by no means implies that in presence of other components the conditions required for the production of an adequate amount of flux should not be more favorable and economical. In other words, the study of other systems may establish the economic possibility of producing a cement containing a high percentage of tricalcic silicate. For example, if some substance were substituted for the component Al_2O_3 in the system $CaO - Al_2O_3 - SiO_2$, the study of the equilibrium relations found to exist in this new system would enable one to determine whether or not it would be economically possible to produce a cement containing a high percentage of $3CaO.SiO_2$ from raw materials of which the components are CaO, SiO_2, and this third substance. Thus if Fe_2O_3 were substituted for Al_2O_3, we could, from the study of the system $CaO - Fe_2O_3 - SiO_2$, ascertain the fineness of the raw material and the time and temperature of burning necessary to secure a clinker containing the highest percentage of $3CaO.SiO_2$ which could be economically produced from raw materials of which the major components are CaO, Fe_2O_3, and SiO_2. This would require that one determine the nature of all compounds formed in mixtures of these three oxides which when burned contain $3CaO.SiO_2$, and that we establish the identity, melting temperature, and rate of formation of $3CaO.SiO_2$ in such mixtures. Instead of substituting a single substance, it would undoubtedly be more desirable to substitute a number of different substances, since the presence of several produces a lower melting flux and thus makes possible the formation of $3CaO.SiO_2$ at a lower temperature. By proceeding in this way to determine systematically the various mixtures of substances which when burned give high percentages of $3CaO.SiO_2$, it would not seem at all improbable that we may discover some mixture which could be economically manufactured and which would

result in the production of a cement far superior to the Portland cement now made.

In conclusion, let us recapitulate the main points contained in this paper. The value of Portland cement depends upon the fact that when finely powdered and mixed with water it forms a hard mass; and the strength and permanence of this mass depend upon the constituents of the cement. The major constituents are tricalcic silicate, dicalcic silicate, and tricalcic aluminate. Of these constituents, the compound tricalcic silicate is the one which hardens and develops the greatest strength within a reasonable time. This most important constituent, which is the one formed with the greatest difficulty, makes up only about 30 to 35 per cent. of an average normal Portland cement. It may be said, therefore, that the essential process for the manufacture of Portland cement is the formation of this compound, and that any improvement in this process yielding an increased percentage of tricalcic silicate will increase the cementing value of Portland cement. In order to determine the most economical process for producing tricalcic silicate in the highest percentages, it will be necessary to study the rate of formation of this compound in a series of mixtures of various substances; this, in turn, necessitates the determination of the equilibrium relations of tricalcic silicate at high temperatures in such mixtures. Such a procedure will lead sooner to the discovery of the optimum composition in various cases and for various purposes than the empirical, cut-and-try methods which hitherto have been the only methods tried.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., March 2, 1916.

THE RULING AND PERFORMANCE OF A TEN-INCH DIFFRACTION GRATING.*

BY

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The principal element in the efficiency of any spectroscopic appliance is its resolving power—that is, the power to separate spectral lines. The limit of resolution is the ratio of the smallest difference of wave-length just discernible to the mean wave-length of the pair or group. If a prism can just separate or resolve the double yellow line of sodium its limit of resolution will be $\frac{5896-5890}{5893}$, or approximately one one-thousandth, and the resolving power is called one thousand.

Until Fraunhofer (1821) showed that light could be analyzed into its constituent colors by diffraction gratings this analysis was effected by prisms the resolving power of which has been gradually increased to about thirty thousand. This limit was equalled, if not surpassed, by the excellent gratings of Rutherford, of New York, ruled by a diamond point on speculum metal, with something like 20,000 lines, with spacing of 500 to 1000 lines to the millimetre. These were superseded by the superb gratings of Rowland with something over 100,000 lines, and with a resolving power of 150,000.[1]

The theoretical resolving power of a grating is given as was first shown by Lord Rayleigh by the formula $R = mn$, in which n is the total number of lines, and m the order of the spectrum. An equivalent expression is furnished by $R = \frac{l}{\lambda}(\sin i + \sin \theta)$, where l is the total length of the ruled surface, λ the wave-length of the light, i the angle of incidence, and θ the angle of diffraction, and the maximum resolving power which a grating can have is that corresponding to i and θ, each equal to 90°, which gives $R = \frac{2l}{\lambda}$ that is, twice the number of light-waves in the entire length of the ruled surface.

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* Presented at the stated meeting held Wednesday, November 17, 1915.

[1] The 6½-inch gratings now ruled on the Rowland engine have a much higher resolving power—probably 400,000.

This shows that neither the closeness of the rulings nor the total number determines this theoretical limit, and emphasizes the importance of a large ruled space.

This theoretical limit can be reached, however, only on the condition of an extraordinary degree of accuracy in the spacing of the lines. Several methods for securing this degree of accuracy have been attempted, but none has proved as effective as the screw. This must be of uniform pitch throughout, and the periodic errors must be extremely small.

For a short screw—for example, one sufficient for a grating two inches in length—the problem is not very difficult, but as the length of the screw increases the difficulty increases in much more rapid proportion. It was solved by Rowland in something over two years.

Since this time many problems have arisen which demand a higher resolving power than even these gratings could furnish. Among these is the resolution of doubles and groups of lines whose complexity was unsuspected until revealed by the interferometer and amply verified by subsequent observations by the echelon and other methods.

Others that may be mentioned in this connection are the study of the distribution of intensities within the spectral "lines"; their broadening and displacement with temperature and pressure; the effect of magnetic and electric fields, and the measurement of motions in the line of sight, as revealed by corresponding displacement of the spectral lines in consequence of the Doppler effect.

All of these have been attacked with considerable success by observations with the echelon, the interferometer, and the plane-parallel plate. These methods have a very high resolving power, but labor under the serious disadvantage that adjacent succeeding spectra overlap, making it difficult to interpret the results with certainty.

Some twelve years ago the construction of a ruling engine was undertaken with the hope of ruling gratings of fourteen inches —for which a screw of something over twenty inches is necessary. This screw was cut in a specially corrected lathe so that the original errors were not very large, and these were reduced by long attrition with very fine material until it was judged that the

residual errors were sufficiently small to be automatically corrected during the process of ruling.

The principal claim to novelty of treatment of the problem lies in the application of the interference method to the measurement and correction of these residual errors.

For this purpose one of the interferometer mirrors is fixed to the grating carriage, while a standard, consisting of two mirrors at a fixed distance apart, is attached to an auxiliary carriage. When the adjustment is correct for the front surface of the standard, interference fringes appear. The grating carriage is now moved through the length of the standard (one-tenth of a millimetre if the periodic error is to be investigated; ten or more millimetres if the error of run is to be determined), when the interference fringes appear on the rear surface. This operation is repeated, the difference from exact coincidence of the central (achromatic) fringe with a fiducial mark being measured at each step in tenths of a fringe (twentieths of a light-wave). As a whole fringe corresponds to one hundred-thousandth of an inch, the measurement is correct to within a millionth of an inch.

The corresponding correction for periodic errors is transferred to the worm-wheel which turns the screw; and for errors of run to the nut which moves the carriage.

In this way the final errors have been almost completely eliminated and the resulting gratings have very nearly realized their theoretical efficiency.

A number of minor points may be mentioned which have contributed to the success of the undertaking.

(*a*) The ways which guide the grating carriage, as well as those which control the motion of the ruling diamond, must be very true; and these were straightened by application of an autocollimating device which made the deviation from a straight line less than a second of arc.

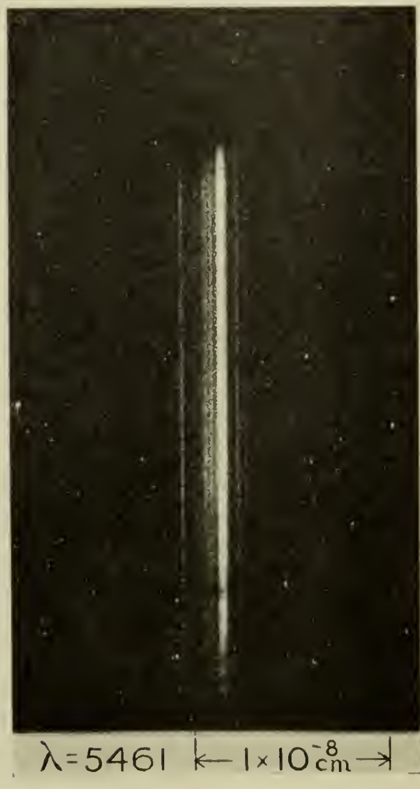
(*b*) The friction of the grating carriage on the ways was diminished to about one-tenth of that due to the weight (which may amount to twenty to forty pounds) by floating on mercury.

(*c*) The longitudinal motion of the screw was prevented by allowing its spherically rounded end to rest against an optically plane surface of diamond which could be adjusted normal to the axis of the screw.

(*d*) The screw was turned by a worm-wheel (instead of pawl and *ratchet*) which permits a simple and effective correction of the periodic errors of the screw throughout its whole length.

(*e*) A correcting device which eliminates periodic errors of higher orders.

(*f*) It may be added that the nut which actuates the carriage



Enlargement of photograph of the green mercury line γ 5461, taken by H. L. Lemon with ten-inch diffraction grating in sixth order. Ruled surface, $9\frac{3}{8}$ inches $\times$ $2\frac{7}{8}$ inches, 11,700 lines per inch. Mounted in Littrow form with eight-inch lens by Brashear. Focal length 20 feet.

had bearing surfaces of soft metal (tin) instead of wood, as in preceding machines. It was not found necessary to unclamp the nut in bringing it back to the starting point.

Finally it may be noted that instead of attempting to eliminate the errors of the screw by long-continued grinding—which in-

evitably leads to a rounding of the threads—it has been the main object to make these errors conveniently small; but especially to make them constant—for on this constancy depends the possibility of automatic correction.

The accompanying photograph made with a ten-inch grating, sixth order (actual ruled surface 9.4 inches by 2.8 inches), used in the Littrow form with an excellent eight-inch lens by Brashear, is given in evidence of its performance. The resolving power as shown by the accompanying scale of Angström units is about 450.000. The original negative shows a resolving power of about 600.000. The theoretical value is 660.000.

Doubtless the possibility of ruling a perfect grating by means of the light-waves of a homogeneous source has occurred to many—and indeed this was one of the methods first attempted.

It may still prove entirely feasible—and is still held in reserve if serious difficulty is encountered in an attempt now in progress to produce gratings of twenty inches or more. Such a method may be made partly or perhaps completely automatic, and would be independent of screws or other instrumental appliances.

It may be pointed out that an even simpler and more direct application of light-waves from a homogeneous source is theoretically possible and perhaps experimentally realizable.

If a point source of such radiation sends its light-waves to a collimating lens and the resulting plane waves are reflected at normal incidence from a plane surface, stationary waves will be set up as in the Lippman plates; these will impress an inclined photographic plate with parallel lines as in the experiment of Wiener; and the only limit to the resolving power of the resulting grating is that which depends on the degree of homogeneity of the light used. As some of the constituents of the radiations of mercury have been shown to be capable of interfering with difference of path of over a million waves, such a grating would have a resolving power exceeding a million.

This investigation has had assistance from the Bache Fund of the National Academy of Science, from the Carnegie Institution, and from the University of Chicago.

In addition to the grateful acknowledgment to these institutions, I would add my high appreciation of the faithful services rendered by Messrs. Julius Pearson and Fred Pearson.

Electrically-driven Rolling-mill Service by a Central Station. ANON. (*Electrical World*, vol. 67, No. 12, March 18, 1916.)—The objections which many central-station companies raise to rolling-mill loads (extreme fluctuations and consequent disturbing effect on line voltage) have been overcome, to a great extent, in the plant of the Central Steel Company, of Massillon, Ohio, by supplying energy to the main motor of its large blooming mill through a fly-wheel induction motor-generator, regulating the slip of the latter, and so exciting the motor-generator and blooming-mill motor that peak energy is absorbed from the rotating fly-wheel, minimizing the disturbances to the electric system. Another feature of the installation is that the blooming-mill reversing motor is connected permanently with the generator terminals without any control apparatus in series, the speed being regulated within the range of 0–r. p. m. to 47–r. p. m. by changing the generator field excitation. The generator and reversing motor are separately excited from a motor-driven exciter set employed especially for this equipment, so that operation is dependent only on continuity of the alternating-current supply and not on the excitation system common to all equipment in the mill.

When an ingot approaches the blooming mill the motor is turned over slowly until the rolls grip the metal, then the speed is increased to 47–r. p. m. to complete the roughing passes. During the finishing passes the motor speed is still further increased by weakening the motor field. Racing cannot occur when the motor is turning over idly before the metal enters the rolls, since the speed is practically independent of the load. This is a distinct advantage over operation with steam engines, since they usually race when operated without load, or come to a standstill when the rolls grip the metal.

At the end of each pass the generator field is de-energized and the mill motor brought to rest by regeneration. During this period it "pumps" energy back into the fly-wheel generator set, thereby speeding it up preparatory to the gripping of the metal in the next pass. Approximately 70 per cent. of the energy required to accelerate the rotating parts of the mill is regained in this manner. Reversal of the blooming-mill motor is accomplished by reversing the direction of the shunt-field current, through the generator, residual magnetism being killed by automatically-actuated, field-forcing relays. In this operation accelerating relays increase the motor torque by cutting in resistance to decrease the field current of the main motor, thereby increasing the current through the motor armature.

Although the reversing motor develops peaks of 8100 horsepower, the input to the alternating-current motor does not exceed 1200 kilowatts. In other words, the central station's generating equipment need not exceed the rating required to generate 1200 kilowatts. Furthermore, the steam economies obtained under such conditions are considerably better than those obtained from operating a reversing engine directly from a boiler plant. At this plant from 20 kilowatt-hours to 30 kilowatt-hours is sufficient for rolling different grades of metal, including vanadium steels.

HIGHWAY PROBLEMS OF THE STATE OF PENNSYLVANIA.*

BY

WILLIAM D. UHLER,

Chief Engineer, Pennsylvania State Highway Department.

The commonwealth of Pennsylvania comprises more than 44,000 square miles of territory. The total road mileage in the state is 97,850, or more than two miles of roadway to each square mile of land. This mileage would have been more than sufficient to have laid out this vast territory along sectional lines, as has been done in some of the western states, which procedure would have simplified the highway problems for the commonwealth.

The earliest settlements in the state were in the extreme south-eastern portion, centring in and about this historic City of Brotherly Love, where William Penn brought the voyagers on the staunch little ship *Welcome* to found his colony as "a religious experiment."

Even before the autumn of 1628, when the *Welcome* arrived, the upper end of the Delaware Peninsula had been settled by the hardy Swedes, and even then the Indians who roamed the old Welsh tract knew the sight of the palefaces.

With Philadelphia established by Penn and his adherents, the growth of Pennsylvania began. Of necessity these early settlers established their system of roads and lanes which later became the city streets. Within five years the more adventurous in the colony had crossed the Schuylkill and pushed into the virgin land to the west and north, and in 1687 the first main highway leading westward from Philadelphia was formally laid out. It was known as the French Creek Road and followed the western bank of the Schuylkill River to the confluence with French Creek, which point later became the site of the present Phœnixville, thence following French Creek to the westward. The highway was opened to a point near the Conestoga Creek, or River, and within a few years was further completed through the town of Lancaster.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, February 24, 1916.

One of the earliest notes made concerning highways in the province was on September 19, 1686, when the attention of Councill was called to "ye unevenesse of ye Road from Philad[a.] to ye falls of Delaware." This was the King's Highway. Another mention in the records is on June 27, 1693, of the main highway between the Swede settlement on the Delaware and the Dutch settlement on the Hudson which, in this later day, we know as the Old York Road. This was laid out over 77 courses, 9610 perches, or 30 miles, and was confirmed January 7, 1713.

So rapidly did the hardy young colony increase in population, through immigration, that the early days of the eighteenth century

Culvert on state highway after improvement.

saw Pennsylvania, east of the Susquehanna River, well in process of permanent settlement. In fact, in those colonial days, when the site of this historic building was well out in suburban Philadelphia, the state of Pennsylvania had acquired through its settlements a road mileage of no mean proportions.

These roughly-made roads, or trails, radiating in different directions from Philadelphia through the southeastern part of the state, were the parent branches from which spread and grew an intricate and complicated system of cross-lanes and by-ways now forming a part of the vast road mileage of the state.

As was the case in nearly every instance in colonial America, the roads laid out followed the general direction of one of three

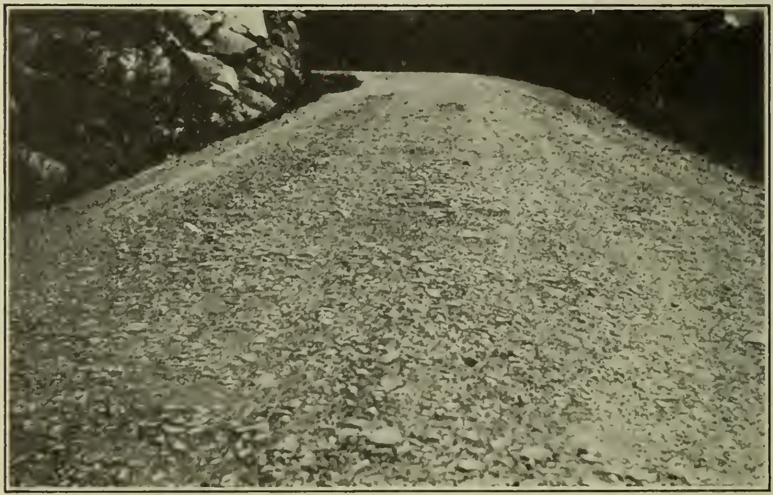
classes of trails: the Indian trail, animal paths, or waterway courses. For a few years the French Creek Road answered the requirements for traffic to the west from Philadelphia, although in the same year that it was opened a road was laid down from the western banks of the Schuylkill River to Old Haverford Meeting House, and in 1690 this highway was pushed still farther

Modern method of applying bituminous surface treatment.

westward, forming the beginning of the famous old Conestoga Road. In 1693 and 1695 this road was extended westward to the Susquehanna. The main line of the Pennsylvania Railroad, from Philadelphia to Lancaster, follows closely the original lines of this highway, although our historic records are misty in their references to its exact location after entering that part of the parent county of Chester which constitutes that county as we now know it. There seems to be basis for the belief that the Conestoga Road originally passed through the village of Goshen, now known as West Chester.

In 1701 a third highway was projected westward from Philadelphia, referred to in the chronicles of the times as the Nottingham and New Kensington Road. Later this highway was continued through the colony of Maryland to Baltimore and became known as the Baltimore Pike.

From these primary arteries, as has been said before, grew the system of cross-roads and interdependent highways belonging variously to the townships and counties. When the State Highway Department was reorganized in 1911, the original plan was to lay out a State Highway System which would connect the county-



Effect of motor traffic on plain water-bound macadam.

seats in the state by means of the most-travelled and most direct roads. This laudable intention was frustrated, in a measure, by the desire of various communities to have greater mileage in their localities added to this State Highway System; the net result being that the Sproul Act, under which the State Highway System was designated, provided for 8800 miles being taken over by the commonwealth. This was far too much. Nothwithstanding this fact, the Legislature of 1913 added more than 1400 miles to the system. Had it not been for the firm stand taken by Governor Brumbaugh, the 1915 Legislature would have continued to increase this mileage by adding other routes to the Sproul system.

This vast mileage falls on the state to maintain and reconstruct.

From the viewpoint of highway efficiency, the system, as constituted, makes for Pennsylvania's greatest mistake. No other state in the Union has attempted the control of so great a road mileage. Rather, the practice has been to take over those highways which have been reconstructed with a permanent type of road material and to assume no responsibility for their maintenance prior to that time.

Far better would it have been for Pennsylvania had a main line system of roadways been adopted directly connecting the county-seats and following the main courses of travel east and

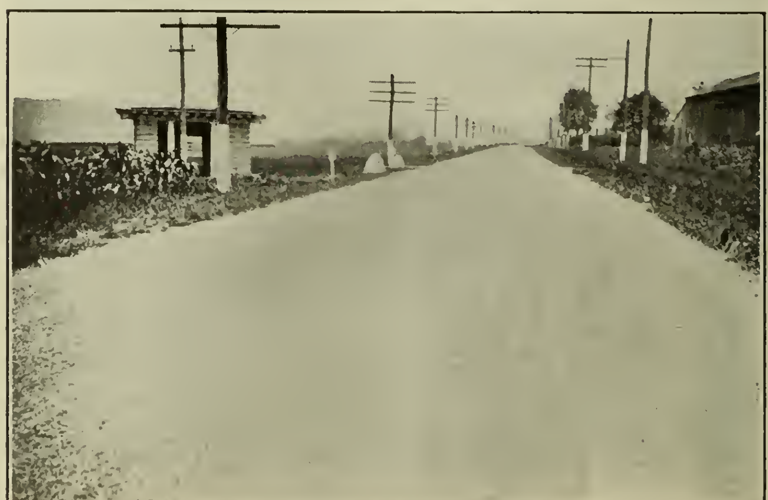
Improved state highway, showing bituminous concrete wearing surface.

west and north and south. This would have meant a State Highway System not exceeding 3300 miles, which would have been feasible and comparatively easy to maintain with the revenues at the disposal of the commonwealth for highway purposes.

At the present time the department is working up such a comprehensive plan of main arteries. It is proposed to secure, if possible, the approval of Governor Brumbaugh to this plan, in which event all permanent improvements in the future will be limited to this main system until it is completed, after which the laterals will be improved from time to time as appropriations become available.

In taking over and assuming the responsibility of 10,200 miles

comprising the system, only a small percentage of which was improved, the state shouldered a burden too great to be carried in a proper manner. To demonstrate the wisdom of the policy adopted in other states, I would call your attention to the fact that the Pennsylvania State Highway Department during 1915 spent approximately four and one-half million dollars in maintaining the present system of 10,200 miles, and, from present indications, will spend during the year 1916 for the same purpose approximately three million dollars, making a total expenditure of seven and one-half million dollars in two years, with nothing of any great moment in the way of permanency to show for it. The work



Bituminous surface-treated state highway.

done during 1915 was the maintenance of 6648 miles of earth, flint, gravel, and shale roads; resurfacing 525 miles of water-bound macadam roads; oiling 1084 miles of roads, and maintaining 1355 miles of stone and other improved roads. These figures show conclusively that the method under which we are working is by far the most expensive way to build up a road system.

Had it been possible to expend this seven and one-half million dollars in permanent construction, from five to six hundred miles of highways could have been improved during the working seasons of 1915 and 1916, which, added to the 1880 miles of roads

already improved, would have furnished a satisfactory nucleus for the permanent highway system of the state.

I might add that it is the policy of this administration to maintain the present road mileage before attempting any new construction work. We have a large mileage of old state-aid roads, together with toll roads taken over, which require resurfacing in order to save what little is left of the original improvement, so that, as before stated, the work done during the seasons of 1915 and 1916 primarily has been and will be that of maintenance. The general practice in handling the various types of roads is as fol-

Effect of traction engine traffic on improved highway.

lows: earth roads, to provide proper drainage and shape by use of road machines and to preserve the shape and contour by the liberal use of log drags; water-bound macadam roads, to resurface and patch where necessary and then to preserve this surface by the use of a bituminous surface treatment; brick, asphalt, concrete, etc., to make such repairs as may be necessary to keep the road in good condition.

After all improved surfaced roads have been repaired they are taken care of under the patrol system which has been inaugurated in the department. This provides for the placing of caretakers or patrolmen in charge of sections of highway from three to five miles in length, depending upon the character of the road to be

maintained. Each patrolman is provided with such tools, material, and equipment to take care of his section of road properly. This method has been found to be not only more satisfactory but also more economical than any other devised for the maintenance of highways.

There is no doubt but that the problems of the Pennsylvania Highway Department have been greatly complicated by the character of the roads unloaded, as it were, upon the state. In a number of cases roads which had been neglected for years and, in some instances, abandoned roads, were deliberately bequeathed

Earth road maintained with log drags.

to the state. As an illustration of this, let me cite one section where five routes, leading north from one of the east and west main highways, were laid down within a distance of 20 miles. One route, 24 miles in length, is not open to traffic at the present time, as a portion of it runs over what is left of the right of way of an abandoned narrow-gauge railroad, the graded road-bed of which, for a greater portion of the distance, is not more than five feet in width. The rest of the location of this state highway follows old lumber trails which it would be necessary to re-locate and grade.

The second route runs along the Susquehanna River. It should be, and undoubtedly was, a very important thoroughfare

to the northwest, but, when the railroad was built along the river, the right of way of the highway disappeared. To put a road of sufficient width in this location at the present time would require either the construction of a retaining wall along the river nearly the entire length of the road, or heavy grading to place the highway between the railroad and the mountain side, as high bluffs are encountered along the whole line. In either event this would mean an expenditure of at least twenty or thirty thousand dollars a mile, exclusive of road surfacing.

The third state highway, in the locality to which I refer, is an historic one which virtually has been abandoned by the local authorities for the past generation. The right of way is covered with underbrush, and but little remains to indicate that it once was a prosperous and much-travelled highway to the frontier.

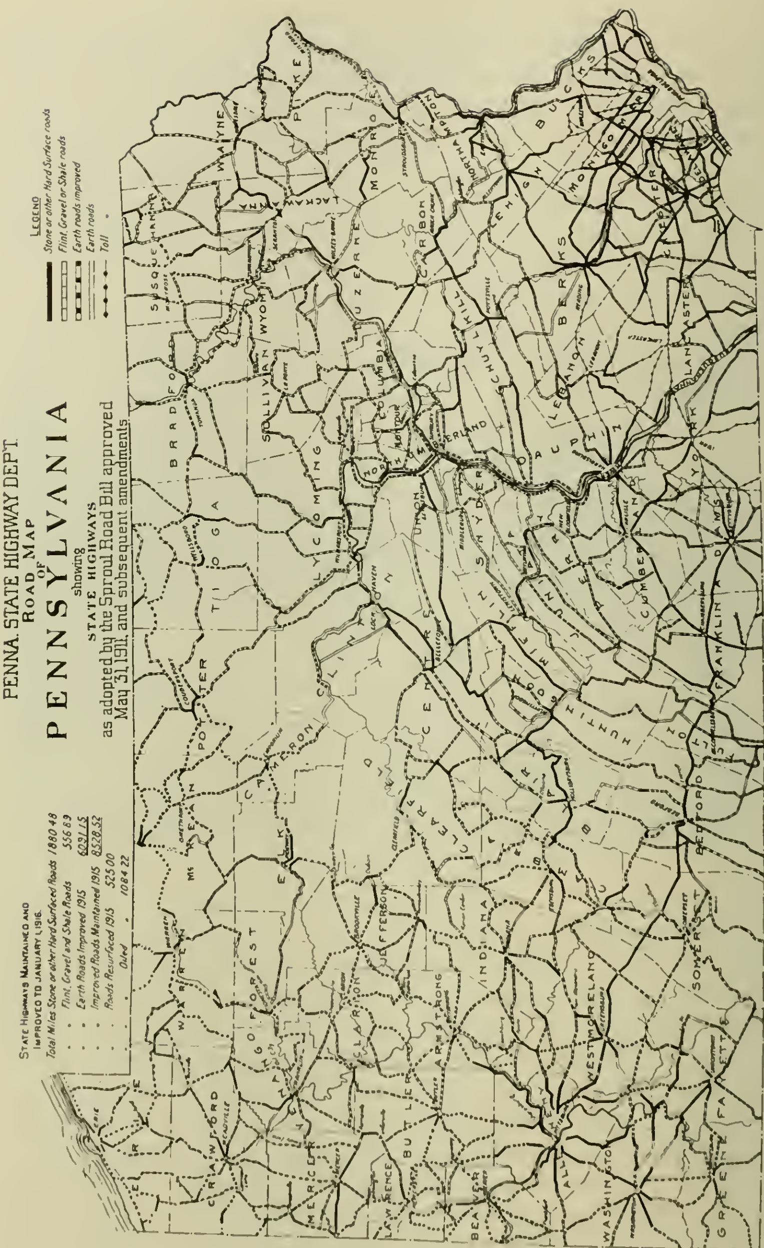
Of the fourth state highway, running off from this east and west trunk line, only a short distance is safe for traffic. The railroad built through here forced the re-location of this highway. In many places it was thrown up on the side hill to permit the railroad company the use of the original location. At several points the road now is not more than 8 or 9 feet in width, with almost precipitous slopes.

The fifth of these highways is the only one that can be put in passable condition at a small expense.

These examples simply serve to illustrate one of the many problems confronting the Department. Of these five roads only one would be used in a main system of highways.

The toll road is another problem to be considered. At the time the Sproul Act was passed there were 717 miles of toll roads in Pennsylvania, of which 521 miles were taken into the State Highway System. Since that time 105 miles of these roads have been acquired by the State Highway Department through purchase, leaving 416 miles still on state highway routes, the major portion of them being in thickly-populated and heavily-travelled sections of the state. The toll roads, as originally built, were of great benefit in the early development of the state, but to-day one looks upon them as a relic of the Dark Ages. They are an anachronism! Nevertheless, this subject is one that must be reckoned with, and the expenditure of large sums will be necessary before all the toll roads are acquired finally by the state.

We should not lose sight of the fact that the improvement of

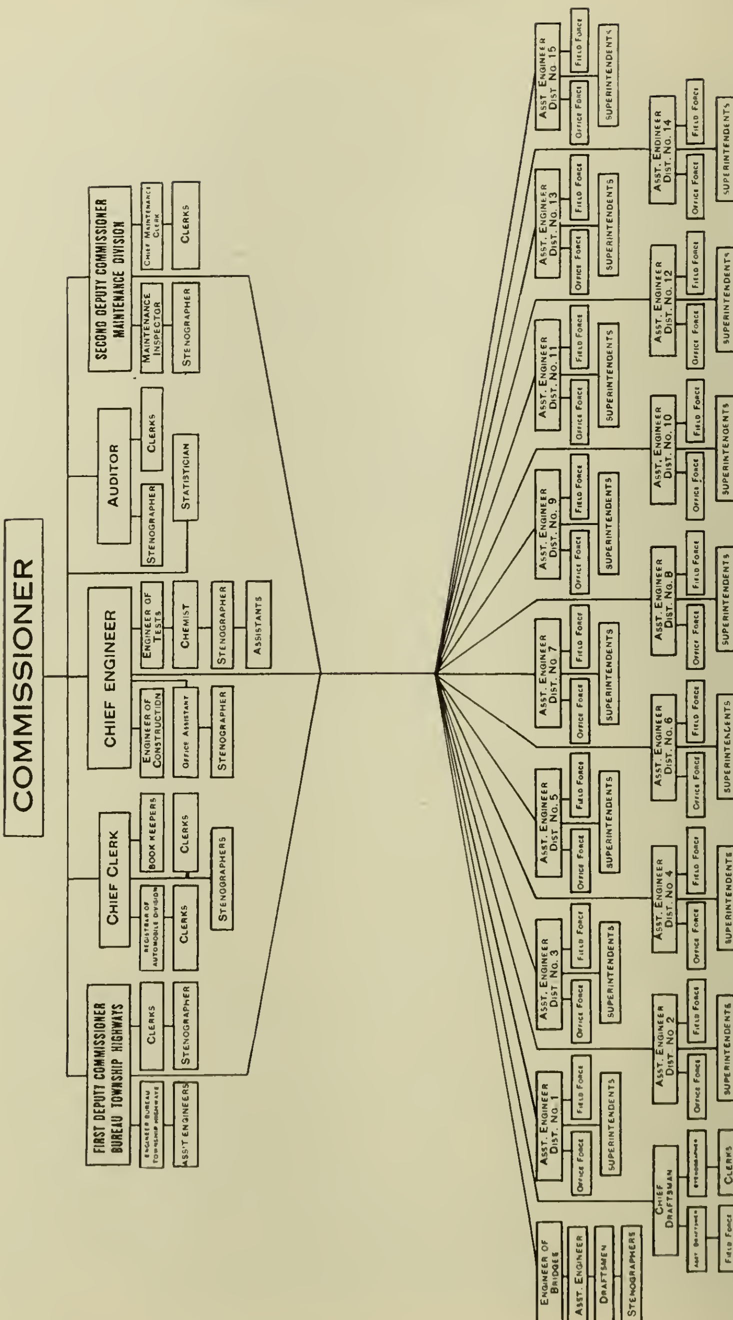

PENNA. STATE HIGHWAY DEPT.
ROAD MAP
OF
PENNSYLVANIA
showing
STATE HIGHWAYS
as adopted by the Sproul Road Bill approved
May 31, 1911, and subsequent amendments
LEGEND
Stone or other Hard Surface roads
Flint, Gravel or Shale roads
Earth roads improved
Earth roads
Toll
STATE HIGHWAYS MAINTAINED AND
IMPROVED TO JANUARY 1, 1916.
Total Miles Stone or other Hard Surfaced Roads 1880 48
Flint, Gravel and Shale Roads 556 83
Earth Roads Improved 1915 6091 15
Improved Roads Maintained 1915 8528 52
Roads Resurfaced 1915 525 00
Oiled 1084 22

our state highways adjoining these toll roads enhances the value of this form of private property and means a consequent increase in the price which the owners demand when the state gets ready to take them over. Most of the toll roads remaining in Pennsylvania are located in the southeastern corner of the state, forming a network of highways in and about Philadelphia, Lancaster, Lebanon, and York.

By far the most important problem in connection with the development of an up-to-date State Highway System is in securing or providing revenues sufficient to permit of the construction of a main arterial system such as I have outlined previously. Whether such funds are to be derived through taxation or by a bond issue is a question to be decided by the public through the Legislature.

Another problem which causes us great concern is that of the maintenance of bridges on state highway routes. The law provides, or at least so it is interpreted, that all county-built bridges on routes are to be maintained by the county authorities, and all bridges originally built or maintained by and at the expense of townships are to be taken over by the state. This means that in many instances the county authorities neglect the maintenance of the bridges on the routes taken over by the state and the state is powerless to compel them to make the necessary repairs. The travelling public, however, not knowing the facts, naturally blames the department for such conditions. In a number of cases the State Highway Department has notified county authorities of the dangerous condition of certain bridges, but has been met either with a refusal to make the repairs or has received no reply whatsoever.

The State Highway Department, of course, has the usual trouble and problems as to the types of road to be built. It is impossible to satisfy every one, but the invariable rule of the department is to consider carefully the local needs and conditions, together with the traffic, grade, original cost, and maintenance charges, before making any decision as to the type to be selected. It is my personal opinion that the time has come when maintenance should be the principal governing factor, as in the construction of such a system of highways as is planned by this state maintenance will be the first item to be reckoned with. There is no doubt but that in the past insufficient attention has been given to the selection of the type of pavement suitable for local conditions.



Organization of Pennsylvania State Highway Department under Act of 1911. 1916.

Allowance must and should be made in the selection of the type of pavement for a constant increase and change in the character of the traffic. The type that made France famous for its good roads, water-bound macadam, as originally constructed and maintained, will not meet the present-day traffic demands of the motor vehicles.

Since the advent of motor vehicles still further demands are made by the constantly-increasing size and weight of motor trucks now being used, which creates an entirely new condition. There is no question but that either steps will have to be taken in the near future to control this class of traffic or else additional revenues must be raised to permit of more permanent types of construction, as the roads built in the past, in the majority of cases, are neither of sufficient width to permit the safe operation at high speed of the trucks as now constructed with bodies practically the size of freight cars, nor are the foundations sufficient to carry these excessive loads.

The state at the present time derives no revenues from this class of vehicles other than the regular motor license fees of from five to twenty-five dollars a year, depending upon the size of the truck. This is another question that must be settled by the public through its legislative body.

The question of experienced help, including engineers, superintendents, foremen, and even laborers, is a problem confronting us at every turn. We have found it impossible to get sufficient skilled assistants, for the reason that road work, along modern lines, is in its infancy. It is necessary to educate the forces, and one of the chief troubles in holding together the necessary road organization is that it is impossible—in fact, impracticable—to provide work for them during the full twelve months of the year. This is because the character of the work will not permit of continuous employment, and it becomes necessary, usually, to lay off approximately 75 per cent. of the force at the close of the working season. This means that the skilled assistants and good laborers look for work of a more permanent character. Again, in certain parts of the state we have found it impossible to secure any kind of labor and this, of necessity, makes necessary the importation of foreign labor, with all of its drawbacks.

In conclusion, aside from the actual building and maintaining of roads, still another and a very vital question is the proper ad-

ministration of the affairs of the department. Too often has it been the case in public office in this country that political preferment has been exercised to so great an extent that efficiency has been impaired.

In appointing Commissioner Cunningham, Governor Brumbaugh gave him to understand fully that he expected a businesslike administration of the State Highway Department; efficiency is the first consideration. Removals, promotions, and appointments, in both the Engineering and Executive Divisions, have been made solely upon merit. The result is that to-day Pennsylvania has an efficient and economically-operated Highway Department.

Water Power and Defence. W. R. WHITNEY. (*Proceedings of the American Institute of Electrical Engineers,* April 26, 1916.)—The United States has no adequate source of fixed nitrogen. Nitric acid is an absolute necessity in the manufacture of any form of explosive stuffs. Ammonia or nitrate compounds are in increasing demand as fertilizers. The present dependence upon Chile is a menace in case of war and involves the payment of export duties and profits amounting to nearly $5,000,000 annually in time of peace. Home production is wholly a question of initiative and proper utilization of water power. Failure to establish the industry in the past has been due to economic conditions, such as the relative proximity of Chile and the impossibility of competing with the cheap water powers of Scandinavia as well as lack of a near-by agricultural demand. The growing need for fertilizers, the desirability of establishing a dyestuff industry, and, especially, the feeling of uncertainty in international relations make a reconsideration desirable.

National safety demands the development of a nitrogen fixation industry, whether it be self-supporting or not. But, the industry once established, the products would be of the greatest value in times of peace and would be stimulated thereby. Thorough industrial organization is the best preparedness for either peace or war. Each of the processes available has advantages. The problem is many-sided and far-reaching, and hence it is very desirable that the various government departments concerned, those of the Army, Navy, Agriculture, and Interior, with their skilled staffs and expert knowledge, should coöperate in determining the course to be taken. Immediate action is very important, since at least two years will be consumed in getting any process available into operation after a decision is reached.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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THE LUMINOUS CRUSTACEANS.

A large number of crustaceans are known to light, particularly some numerous forms that live for the most part in very deep water. Practically all of the luminous species are pelagic or bathymic in their habit, and we find some quite simple sorts of light-organs as well as some of the most highly differentiated and organized kinds. As in the cephalopod mollusca, two chief sorts can be distinguished: those that have an external form of combustion and which squirt the luciferine out into the sea-water, and those that have an internal form of combustion (oxidation from the blood) and have their organs furnished with reflectors, lenses, etc. It can also be noticed that the various types of organs have developed quite independently and have no phylogenetic or evolutionary relationship with each other.

We will consider the following groups of organs: 1. Those found on the Ostracod. 2. Those met with among the Copepoda. 3. The light organs possessed by the Schizopod crustacea. 4. The decapod types of light organs.

Ostracoda.

Mangold gives a very complete account of the various works that have been done on the Ostracods (see Fig. 1). Godeheu de Riville first noticed, in 1754, great quantities of these small crustaceans in the waters of Malabar giving out a sky-blue light. Müller mentions this and further tells of a number of species of this group that showed light, as *Pyrocypris chierchiæ, Pyrocypris rivillii, Pyrocypris mollis, Cypridina gibbosa,* and, most remarkable, he makes the statement that *Conchoecia clausii,* a fresh-water species, gives light. If true, this is the only kind of organism living in fresh water that has been known to give out light. It seems to be an error.

* Continued from page 696, May issue.

Among others who saw the light from marine Ostracods are Claus, Chierchia, Mortensen, Hansen, Tilesius, and Döflein. The latter has made the latest and most complete study of the subject and actually described the structures of the organs through which the phenomenon is brought about. No satisfactory physiological studies have been made of the subject beyond a few rather superficial notes.

It was noted by several of the earlier observers that the light material was burned externally and, further, that it was produced in extraordinarily large quantities. Mechanical stimuli, as well as a few cases of chemical stimuli, were employed. In one case the

FIG. 1.

General view of an Ostracod crustacean. The whole group of very many sorts are remarkably alike in size and form. The integument is evaginated from the dorsal line as two lateral shells that cover the body and limbs. The black eye is seen. (After Müller.)

small animal was thrown into alcohol and the light persisted for nearly fifteen minutes. This evidently indicates that an internal light is also possible. In corrosive sublimate the creature gives one strong flash and then all is dark. Evidently the sublimate has a greater power of penetration than the alcohol. The luciferine continues to light in the water in which the animals have discharged it for a long time and with great brilliancy. When a number of the crustaceans were shaken in a vessel of sea-water one could read by the light.

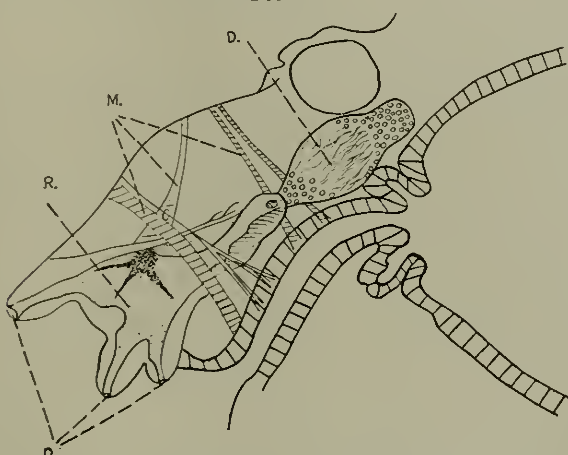
Döflein has shown much of the structure of the organ (see Fig. 2). It consists of an invaginated reservoir that opens through the upper lip of the animal through three separate ducts (O). Müller shows these ducts in *Pyrocypris* as seven in number, also opening through the upper lip. In Fig. 2 this reservoir is shown

by the stippled area. Its structure, or rather the structure of its walls, has not been sufficiently worked out.

At the bottom of this reservoir is a secondary invagination, the luciferine gland (D), in which that light-producing material is secreted. The structure and position of its constituent cells are not more than indicated, and they should be carefully studied at some future time and an attempt made to distinguish between a luciferine and a luciferase type.

The gland evidently secretes and stores up a large quantity of the material in the reservoir. This will explain the large amount that is suddenly ejected. The method of ejection is easily seen when the diagram is examined. Several bundles of muscle-

FIG. 2.



Schematic drawing of the anterior part of the head of the Ostracod *Pyrocypris*, showing the upper lip, in which are seen fine canals. *O.*, openings through which the luciferine is discharged; *D.*, light-gland; *R.*, luciferine reservoir; *M.*, muscle-fibres that compress the reservoir, and thus discharge the luciferine. (After Döflein.)

fibres (M) pass from the dorsal wall, of the head cavity in which the gland and reservoir lie, to its ventral wall just over the œsophagus. When these muscle-fibres contract the reservoir is put under considerable pressure and the stored secretion is forced out of the openings in the lip (O).

Several pigment-cells are associated with the reservoir, although they do not seem to take any part in its operation. It is possible that when the organ is active these chromatophores can be extended in such a way as to cut off any light existing inside the reservoir and prevent it from shining on the brain or other internal parts.

Copepoda.

The lighting of various Copepods is one of the best-known facts in our knowledge of the crustacea. The facts were reported by a number of early writers among whom are Boeck, Buckholtz, Dahl, Vanhöffen, Apstein, and Kiernik; but it was the long-continued, careful, and ingenious work of Giesbrecht at Naples that made the idea so widespread that amateur zoologists and even intelligent travellers would say "Copepods" when they saw any luminosity in the wake of a steamer at sea.

Owing to their small size and to the suddenness of the light, also to the large numbers of different kinds that are usually caught in the net at one time, it is very difficult to lay one's hands on the particular individual that has made the flash and to make it repeat the act under conditions that allow the investigator to be certain that it is a luminous Copepod.

Consequently we have had many such determinations made in the past that have been contradicted or even proved to be erroneous. This proof (a negative evidence) is even harder to establish than the proof that a form is light-producing. We will therefore content ourselves with examining a few of the well-known luminous forms in which we can be certain that the light-producing power is present.

The first of these forms consists of several species of the genus *Metridia,* which will be treated of more or less collectively because of some doubt as to their specific determinations and also because of our lack of knowledge of the structure of their organs. In 1864 Boeck observed on the coast of Norway two forms, probably *Metridia hiberinca* and *Metridia longa*, which when disturbed gave out a strong blue light. Later, Buckholtz noted a luminous Copepod which he called *Diaptomus castor,* but which was probably *Metridia longa.* They were found in Spitzbergen in large numbers in 1874. The light appeared, when the animal was disturbed, on the head and seemed to spread all over the thorax or even the posterior part of the body.

In 1875 Lilljeborg observed these creatures again in Spitzbergen in the months of December and January in the bays. His attention was called to them by the fact that the wet snow lining the shores showed numerous points of a greenish-blue light, and upon examination he found that the little waves from the bay (Mosselbay) were throwing spray and water over this snow and that the Copepods were thus deposited through its upper layers.

Of course, the snow had a temperature in the neighborhood

of the freezing-point, and the animals, being caught and held helpless, showed what the writer has often seen, a steady, somewhat weak, but long-enduring light. When free and at home in the sea they gave only a few stronger flashes when mechanically disturbed. Nearly all of the flashing forms have this same " distress reaction," and it may extend to a point where the organism is actually dead and for some time after. Its explanation probably lies in the breaking down of the vital activities by which the stored luciferine is protected from the action of the surrounding oxygen or luciferase, or both, so that the stored supply of luciferine is slowly consumed.

Vanhöffen had an opportunity to study *Metridia longa* at Karajak, in North Greenland, in February, 1893. He placed the animal in a drop of sea-water under a cover-glass and saw the lighting with a microscope. .The light appeared in the posterior region of the head or on the neck (if a Copepod can be said to possess a neck). At times the light appeared to extend over the entire body. When the cover-glass was pressed with a needle the light streamed out from the body in clouds in the water. When *Metridia longa* was examined with the microscope in daylight it was seen to be colorless except for two moss-green spots on the posterior part of the head and other greenish spots on the last abdominal segment. These green spots appeared to be the light-glands. The green color appeared to be due to the color of the secreted luciferine rather than to the tissues of the gland or its surroundings.

Vanhöffen decided that the light was due to the secretion of glands, but was not certain as to whether this secretion lighted while still in the glands or only upon its discharge into the surrounding sea-water. It appeared to him that it might very well be an internal lighting, and that the streaming out of the luminous substance might be due to the pressure on the organism's body when it was squeezed between the glass slide and cover-glass and a consequent rupture of the surrounding tissues.

Knowing the uncertainty and the many contradictory reports concerning the lighting of Copepoda, Giesbrecht paid particular attention to the subject during the many years of his patient and careful labors on this group at the Naples station. As a result of these careful observations he proved that many careless or hasty reports were not founded on fact, and he definitely established

the light-producing powers of five species that are found in that region. These five species are as follows:

Family *Centropagidæ: Pleuromma abdominale, Pleuromma racilis, Leuckartia flavicornis, and Heterochæta papilligara.*

Family *Oncæidæ: Oncæa conifer.*

His method was to filter quantities of tow, that contained a medium number of Copepods alone, through a bolting cloth or other filter. As the water went through and the animals were left stranded on the filter some of them gave out sparks of light. This was best seen in the first months of the year when the filter would sparkle with numerous points of light, so bright that they could even be seen in a room in ordinary daylight. In the summer and fall, however, the light was not seen, showing that the power was developed only in the late winter and spring.

Thus we see that, as in other forms, only a few species of Copepoda can really light: four kinds out of the hundred or more that are found in the Bay of Naples that is very rich in these forms. Undoubtedly other luminous species will be discovered upon search in other waters, but to date these five and the Arctic forms, *Metridia longa* and *Metridia hiberinca,* are the only seven that can be named as having the light power. Giesbrecht was able to establish the non-luminous character of a large number of species found among twenty other genera from Naples.

Giesbrecht studied the form *Pleuromma abdominale* (Fig. 3) by isolating fresh-caught individuals on a slide in a few drops of sea-water and covering them with a cover-glass. The amount of water was such that the Copepod was not pressed upon hard enough to harm it in any way, and at the same time it was held firmly enough to keep it from changing its position easily. He found it necessary to control the conditions of light and darkness in the room because the chitenous shell was apt to reflect the daylight in such a way as to simulate a flash of autogenous light or even to mask a real display.

As a means of stimulation he first employed a tapping or slight pressing on the cover-glass with a needle. Then the temperature was raised and, finally, various chemical means were employed, as adding distilled water, glycerine, formol, sublimate, and several kinds of strong acids and alkalies.

Under the weaker of these stimuli he saw spots of light appear

at various points on the body, which he recognized as the points at which certain moss-green flecks appeared by ordinary daylight. Further, he recognized these spots as the seat of integumental glands, such as are common at many various points on the body of all Copepoda, excepting that they have the moss-green color only in case of their being light-organs.

When stimulated more violently the light not only appeared at these spots, but was forcibly ejected from the mouths of the glands, so hard in some cases that it lighted for some distance from the

FIG. 3.

General view of the luminous Copepod crustacean *Pleuromma abdominale*. *L.* indicates the position of some of its eighteen light-glands, which in the living animal are moss-green in color and which discharge the stored luciferine. (After Giesbrecht.)

body of the animal, as much as its own length. The light seemed green rather than blue in color.

The various light-glands were counted and located. They formed very definite organs, always appearing in the same places in different individuals of the same species (Fig. 3, *L.*). The form being studied, *Pleuromma abdominale*, has eighteen of such glands, of which only a few are shown in Fig. 3. Giesbrecht enumerated them as follows: three—one median and two lateral glands—lie close together in the forehead. Four form a pair on each anterio-lateral corner of the second thoracic segment. Four

more appear as a pair on each posterio-lateral end of the anal segment, a pair is found on each side of the distal part of the furca, and a single organ is placed just above the pigmented organ. Two more appear on the under side of the head near the organ of the mandibles.

These glands were fairly large, pear-shaped, and lay close against the shell. Unfortunately they were not studied in sections as to their cellular structure and nerve and blood supply. The number and arrangement of the light organs were exactly alike in both sexes. In all of the luminous forms the light-organs went back into the earlier stages, as is common in crustaceans and insects. The organs were best traced back in the several larval stages of *Pleuromma abdominale*. Thus the IV and V Copepodid-stages were shown to have exactly the same number and arrangement of light-glands. The I–III stages appeared to have very much the same number and position of light-organs, but Giesbrecht was not quite satisfied that he had correctly seen and counted them. He felt that all glands were not present in these younger stages. In the first week in January he found a large number of Nanplins stages that seemed to belong to *Pleuromma abdominale* or *Pleuromma gracile,* and each showed three light-organs: one on the forehead, as in the adult, and two small ones on each side of this median gland.

Pleuromma gracile has seventeen light-organs, arranged in much the same way, while *Leuckartia flavicornis* has only ten. All of them showed the same moss-green color and are evidently the same sort of gland. *Heterochæta papilligera* has light-organs that are of a much paler green color than those just mentioned, and also the glands seem to be almost entirely emptied when the animal is first caught and picked out for study under the microscope. Therefore, it was not possible for Giesbrecht to count the glands or study their operation. This species seemed to have more than eighteen, however. They appeared to be arranged in pairs and groups that either possessed a common duct or had their single ducts very closely placed together. Some of the glands were located as follows: two pairs in the head, with ducts opening laterally; three glands on each side in the anal segment; one in the furca; three in each basal joint of each antenna; two in the distal part of each maxilla; two or three in the third joint of the second, third, and fourth swimming foot, besides a number of others in different parts of the body.

Oncæa conifer (Fig. 4), a form belonging to an entirely different family, showed a quite different appearance and arrangement of the light-glands. They were more irregular and larger, with shorter ducts in the head, while those in the abdomen possessed longer ducts and were still larger. The size varied with the condition of fulness or of exhaustion of the secretion. Also the light material (luciferine), which seemed to consist of large droplets of a greenish oil in the above forms (Centropagidæ), was here of a granular nature, as seen *in situ* in the living animal. Furthermore, the light which was decidedly greenish in the former described animals, was of decided blue in this case.

Only the secretion of the body glands lighted in *Oncæa*. Those on the limbs did not. Nor were the light-glands segregated into

FIG. 4.

Lateral view of the luminous Copepod, *Oncæa conifer*. (After Giesbrecht.)

groups, but were scattered all over the surface of the body, especially the back. They were much more numerous than in any of the other forms, although they were not counted as exactly as could be wished. At least thirty were present on the head alone, and the total number must have been more than seventy in all. More were present in the larger female than in the male.

We still lack any idea of the cellular structure of these glands. Giesbrecht considered them to be physiological modifications of the integumentary glands that are numerous in the Copepods, and is probably quite right in this idea. It would probably not be difficult to see them in total specimens that had been fixed in any picric-acid fixing fluid and stained in bulk in carmine or picric-hæmatoxylin. Nor would it be difficult to cut sections, in the writer's opinion, and to see their structure with iron hæmatoxylin or any

other of our best stains. This would be one more of the many interesting pieces of work to be done to enlarge our knowledge of the luminous animals.

Giesbrecht found that it was quite easy to place these five sorts of Copepods upon a bit of dry filter-paper and to dry them out in a current of air in a window without the loss of the light secretion. He kept them dried in this way, and days or months afterwards was able to moisten them and see the light reappear. He could also keep them, dead, for some time, in glycerine and then, by placing them in sea-water, again get the light. The secretion consisted, as above stated, of greenish-yellow droplets or of granules, all of which appeared homogeneous. They were not any form of living protoplasm, but a lifeless material of specific chemical composition which retained its power to light after the death of the tissues, and especially after being kept in a dry state.

Giesbrecht made many experiments by treating the secretion with common chemicals. But, since he did not know of Dubois's experiments and discovery of the catalytic agent called luciferase, his work in this line has not sufficient value to form a part of this treatise. He did note the fact that each of the green-colored light-glands lay in the neighborhood of some of the colorless and undifferentiated integument glands, and it seems to the writer highly probable that those same integumental glands probably secreted the luciferase.

The biological meaning or ecological use of the light to the Copepods was well stated by Giesbrecht. He noted that it cannot be a sex lure through the eye, because, while some of the seven luminous species have very small eyes, the majority have no eye at all. It is probably used as a sacrifice lure. The animal, when disturbed or attacked, shoots the light-cloud out and then swims away, leaving the fast-disappearing light material to claim the attention of its enemy while it escapes itself. It can hardly be a warning signal, as all of the copepods are readily eaten by certain other animals.

One group of broad, flat Copepods, the family Corycædiæ, are noticeable for the magnificent color that is found on parts of or on all of their bodies. The best-known member of this group is the species *Sapphirina ovatolanceolata*, a pelagic species that is common in the waters of the Bay of Naples. The color of this and the allied forms is due to diffraction phenomena caused by the

structure of the integument. As they move, the reflected light appears in all the colors of the spectrum, and one sees them sparkle with everchanging hues of green, gold, blue, violet, orange, etc. Several writers have mistaken these brilliant colors for autogenous light, and some serious descriptions have been written of this phenomenon in that error. Such a mistake is easily made, as can be seen from the following: Some graduate students of Princeton University took another species of this group in the tow at Montego Bay, on the Island of Jamaica. While going over this tow at night by weak lamplight to pick out all luminous forms for the writer, they took this animal for a lighting form, because, at intervals, it gave out a bright orange to ruby-red light from its posterior end. Upon examining it carefully in Princeton during the following winter, after it was preserved in formol and alcohol, it was found that the " light " was still present. In this organism the diffractive structure was present only in two of the large, flat appendages of the tail, and as the creature swam and turned, they shone by the reflected light, whenever the angle was right between the lamp, the object, and the observer's eye. Under the microscope they could be turned in a glass tube so as to show the most beautiful and brightest colors. We have in these organisms some of the most deceptive resemblances of a real autogenous light production.

Schizopoda.

The Schizopoda form a group of the higher crustacea, being one of the suborders that compose the lower half (in morphological value, but not in numbers) of the order Podophthalmata, of which the familiar sub-order of Decapoda form the higher part. There are two families of the Schizopoda, the *Mysidæ,* which have no luminous members, and the *Euphausidæ,* many of whose members are light-producing. It is with these that we will deal in the following pages.

There are many species of these medium-sized, shrimp-like animals, and they are found in all seas, mostly leading a pelagic life, some few on the surface, many more in depths of from 25 to 1000 metres. They are commonest near the bottom and in intermediate depths of about 300 metres.

One of the earliest observations made on these animals was that most of the forms were provided with a number (ten) of

round, pigmented, eye-like organs placed on the first four abdominal segments between the bases of the swimming legs, as well as on the underside of the thorax and on the eye-stalk. From their rounded shape and the presence of a lens, an iris-like opening, and many other features, these organs were taken to be simple eyes, like the ocelli of insects, and they were called the " accessory eyes " by many naturalists, including such specialists in the crustacea tribe as Claus, and others as well known. It was the practical experience in the field obtained during the *Challenger* Expedition that led Sir John Murray and G. O. Sars to learn that these were not organs to receive light (an eye), but that they were organs to produce and discharge light—real light-organs. Patten erroneously clung to the idea that these were real eyes as late as 1886.

Since that time papers have been written on the structure and physiology of these organs by Vallentin and Cunningham (*Nyctiphanes norvegica*), Chun (several genera), Giesbrecht (several forms), Hansen (several genera), Illig (*Gnathophausia*), Trojan (*Nyctiphanes conchii*), and others.

Taking advantage of these several careful investigations, the writer will attempt to generalize and describe the general principles on which these organs are constructed, with some reference to their origin and development and their use in the several forms.

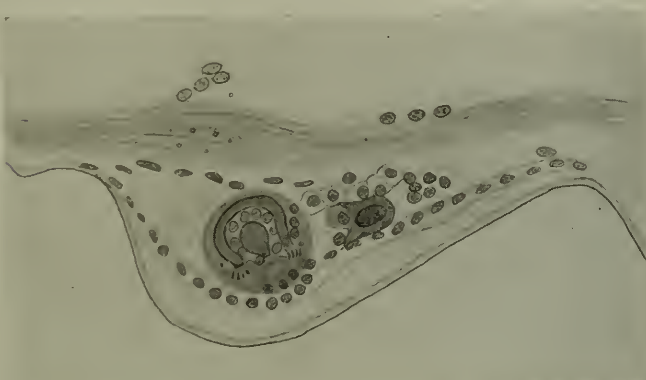
In the majority of the luminous forms the organs are ten in number and are distributed as follows: Two are found, one each on the outer portion of the eye-ball or eye-stalk. The outer surface of this organ is flush with the general surface of the eye. Four occur as two pairs placed on the lower outer edge of the thorax—one pair near the origin of the second thoracic feet, and the second pair near the origin of the seventh pair of thoracic feet. These round structures protrude for more than half their diameter from the general surface of the body. The remaining four photospheres, as these organs are called, are placed on the median ventral surfaces of the first four abdominal segments, between the bases of the swimming legs. Each of these latter organs is placed directly under and partly imbedded in the substance of the nerve-ganglion belonging to the segment on which it lies. Fig. 5 shows this condition.

This arrangement holds for the large majority of luminous *Euphausidæ*, and we do not find any form that possesses more

than the ten organs noted above. On the other hand, there are many that show a smaller number, running down to only three in the genus *Stylochiron*. In cases where the organs are less than ten in number the first organ that is missed appears to be the posterior abdominal organ. When several abdominal organs are absent in any form, then the first or most anterior pair of thoracic organs also are not developed. The eye-organ appears to be absent only in extreme cases, as in some species of *Stylochiron*. Fig. 6 shows the lights as they appear in *Nyctiphanes norvegica* during their living activity.

In the structure of the organs we find two types in nearly

FIG. 5.



Lateral view of an abdominal light-organ or photosphere of *Nematoscelis mantis* to show its relation to the nerve ganglion. (After Chun.)

every species. First, and for certain reasons the most primitive, is the type of organ found on the eye-stalk. Secondly, we find, as a more specialized type, all the other organs, which are practically the same in size and structure in any given species. These thoracic and abdominal organs are more highly differentiated than the eye-stalk organs.

Fig. 7 and Fig. 8, A and B, show one of these eye-stalk light organs from *Nematoscelis rostrata* and two stages of the same organ from *Stylochiron mastigophorum*. We will consider the various layers and structures from the proximal, rounded end of the organ outward.

The first region that is noticeable, especially in life, is a thin

layer of pigment, of a color that is usually Cinnibar red in these species from deeper water, but that is red-brown or even black in

FIG. 6.

Drawing of *Nyctiphanes norvegica*, swimming about some gulf weed that has drifted in by a stone pier. (Drawn by Bruce Horsfal after descriptions by the writer.)

some of the species living inshore or in shallower waters. This layer is composed of flat polyhedral cells (*P.*) and extends distally

about half the length of the organ, or as far as the real reflector extends. It appears to be a mesodermal structure, and its cells and nuclei can be seen to form a transition at the edges into the mesodermal connective tissue of the stalk. The pigment is very delicate in most of the forms and is seldom preserved in the usual fixa-

FIG. 7.

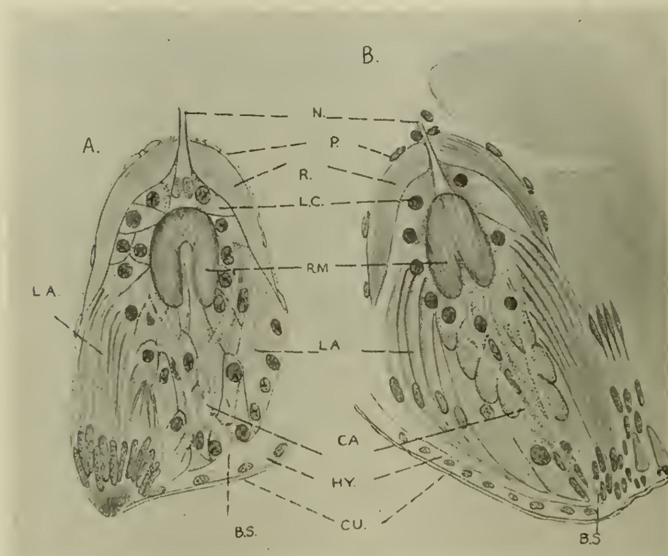
Drawing of a section through the longitudinal axis of the eye-stalk light-organ of *Nematoscelis rostrata*. *N.*, nerve; *P.*, pigment; *R.*, reflector; *L.C.*, light-cells; *R.M.*, rod mass; *La.*, lamellæ; *Ca.*, capillaries; *Hy.*, hypodermis; *Cu.*, cuticle; *B.S.*, blood-sinus. (After Chun.)

tives. The form of the cell-bodies remains, clearly seen, however, and can be distinguished clearly in Flemming and other good preservations.

Directly distad of the pigment layer comes the reflector (*R.*), which also appears to be mesodermal in origin and forms a thick refractive layer enveloping the posterior half of the organ. It

forms a deep, narrow cup or a somewhat wider, shallower one, according to the species, or to whether it is an older or younger specimen. Its tissues are for the most part composed of waved strands or plates of some dense, deep-staining substance that is not guanin, and it loses most, but not all, of its reflective power when treated with the usual reagents and mounted in balsam. Its distal edge is thinned down to a sharp rim, and no nuclei are to be found in its body. Nor can we determine which layer of cells,

FIG. 8, A AND B.



A younger (A) and an older (B) eye-stalk light-organ of *Stylochiron mastigophera*. Lettering same as in Fig. 7. (After Chun.)

the proximal pigment-cells or the next distal (inner with respect to the organ) layer of cells, is responsible for its origin and maintenance.

The next distal or inner layer of cells are thick, heavy gland-cells with strong, working nuclei. Their cytoplasm is filled with a granular material, and they are without doubt the specific cells of the organ, the luciferine-secreting cells or light-cells (*L.C.*). They form a single layer in nearly all cases, although sometimes they may lie obliquely over one another so as to form two layers

in places. As an evidence of their function and importance they are supplied by nerve-fibres and with a large, well-distributed blood supply. The large single nerve (*N.*) approaches them from the proximal end of the organ, where it penetrates both pigment layer and reflector and its branches spread and divide, to be lost among the individual cells. The blood supply, on the other hand, approaches from the opposite or distal pole of the organ as a large vessel that divides and spreads radially, to also end as fine branches that pass as a plexus of capillaries among the light-cells (*Ca.*). The return of this blood is probably in the same direction through another vessel into the large distal sinus that will be described below.

The inner surface of the cup-shaped layer of light-cells is in contact with the outside of another cup-shaped structure, the rod-mass (R. M.), which here seems to be a distal outgrowth of the main body of light-cells. The rods that compose this body are mostly directed in a parallel direction, distally, and they present an optical appearance that leads one to suppose them to be organs of refraction. In some of the organs of this type, especially the organs of larval stages, they appear to extend to the distal surface of the photosphere, and to the writer they seem to be a modified chitenous secretion of the light-cells. They thus stand, as one factor, in the evidence that these light-cells were invaginated from the hypodermis and that they thus have, in common with most other light-cells, an ectodermal origin.

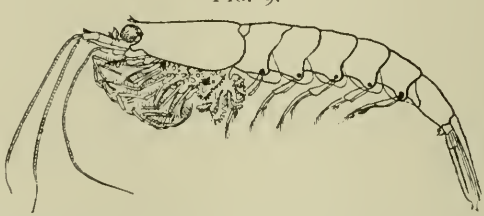
There are still several puzzles to solve as to their use in the organ. The distal cells of the light-organ pass over their edge and appear to fill the hollow of their cup-shaped body.

We now have to deal with the most peculiar structures in connection with the organ, the lamellæ (*La.*), as they have most often been called. These are a series of strong strands or plates that form a circular collar extending from the external chitin of the eye-stalk down to the distal edge of the cup-shaped reflector. In fact, in many, or even in most, forms they appear to be a part of the reflector. Trojan has called the structure the "external reflector," but the writer cannot agree with this. While they are also dense and refractive, they still show differences of appearance and of staining power, and in one point at least we can be clear: they are of direct epidermal origin. There is a clear and direct transition of the general outer hypodermis of this part of the eye-

stalk into these cells in the eye-stalk organs, and they are also continued into the hypodermal cornea that covers the outer face of the organ. Fig. 8A, shows this with especial clearness. Their nuclei are very large, somewhat elongate to fit the spaces between the lamellar rods, and form a direct row continuous with the nuclei of the hypodermal cells.

A blood-sinus (*B. S.*) of some extent lies between the outer surface of the light-cells and the external cornea in *Nematocelis* but is poorly developed in *Stylochiron*. The latter is, therefore, the more primitive in structure of the two forms, and also the most primitive of any of this class of light-organs that we know. We can but speculate as to the first origin of this type of organ. An invagination to form the light-cells, the formation of the

FIG. 9.



Lateral view of *Nyctiphanes norvegica*. The positions of the light-organs are indicated by black dots. Three of them, one eye-stalk organ and two thoracic organs, being on the other side, are not represented. (After Watasi.)

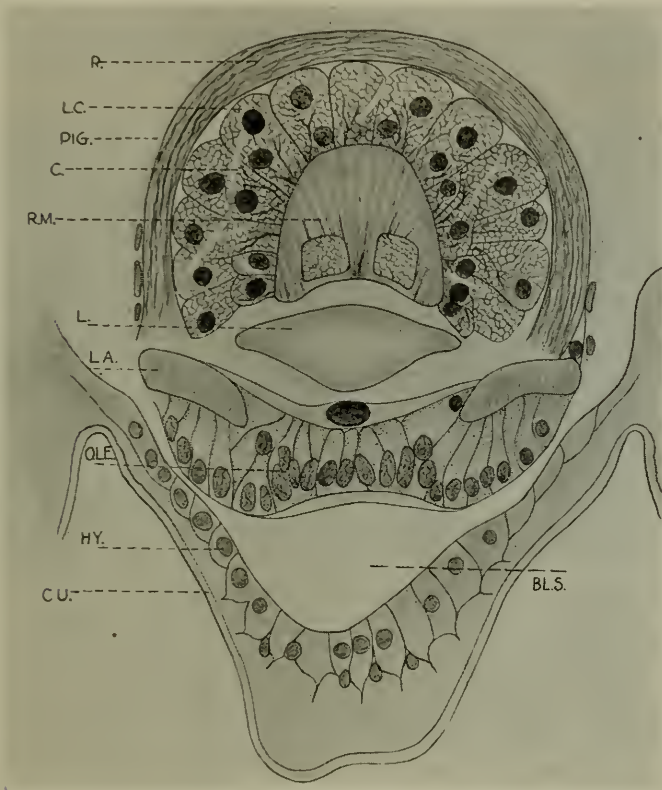
external cornea by the closing of the opening and the lengthening of the peripheral hypodermal cells some distance from the original point of invagination to form the lamellæ, is the most probable course of events in this process.

Let us now turn to the other type of photospherium as seen on the thorax and abdomen of these animals. We evidently see here an organ that is built upon the same ground plan, but which has had other accessory structures added to it and has had some of the original structures changed to meet the new conditions. Fig. 9 shows a lateral view of *Nyctiphanes norvegica*, with the organs shown as black dots.

The abdominal light-organ of *Nyctiphanes norvegica* has been studied by many and is probably one of the most highly developed and characteristic photospheria in the group. The corresponding organ of *Nematocelis mantis* will serve to show a photospherium of the simpler structure in this type. Fig. 10 represents a section of the light-organs of *Nyctiphanes norvegica*,

and Fig. 11, A and B, shows sections of the abdominal light-organs of *Euphausia gracilis* (A) and *Nematocelis mantis* (B). In general it can be remarked that these organs have not only become more differentiated, but that the whole structure has assumed a more compact and rounded shape and has grown to be partly

FIG. 10.



Section of a photospherium of *Nyctiphanes norvegica*. *Pig.*, pigment-layer; *R.*, reflector *L.C.*, light-cells; *C.*, capillary; *L.*, lens; *La.*, lamellæ; *O.le.*, outer lens; *R.M.*, rod mass; *Hy.*, hypodermis; *Bl. S.*, blood-sinus; *Cu.*, cuticle. (Drawn by E. Grace White from a preparation.)

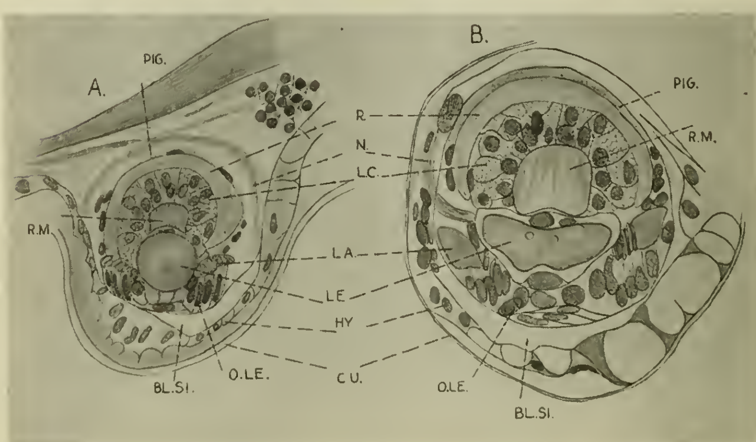
freed from the surrounding tissues, partly because of large intervening blood-sinuses and partly because of more sudden transitions between the tissues of the organ and the general body tissues.

Beginning with the proximal part, we find the same layer of pigment (*Pig.*) lying on the outside of the cup-shaped reflector

(*R.*). There is practically no difference between their structures as seen here and as seen in the eye-stalk organ, except that the "cup" is usually wider and shallower in the second type of organ now under consideration. Nuclei are present in the pigment-layer, which here is composed of two or three layers of flat cells with large, flat nuclei. No nuclei can be seen in the body of the reflector, and it is still a question if this structure is formed by the pigment-cell layer or by the inner (distal) layer of light-cells.

These light-cells (*L. C.*) present no real difference from those

FIG. 11.



Sections of the abdominal light-organs of *Euphausia gracilis* (A) and *Nematocelis mantis* (B). *Pig.*, pigment-layer; *R.*, reflector; *R.M.*, rod mass; *N.*, nerve; *l.c.*, light-cells; *La.*, lamellæ; *le.*, lens; *o.le.*, outer lens; *bl. si.*, blood-sinus; *Hy.*, hypodermis; *cu.*, cuticle. (After Chun.)

described for eye-stalk organ. The same large, active, glandular bodies and semi-epithelial arrangements of the units are shown, as well as the same character of nuclei. We see, too, a well-developed plexus of capillaries running between and through the cells. The layer is supplied with nerve-endings from fibre-trunks that approach it, not from the extreme proximal pole of the organ, breaking through pigment and reflector, but by several smaller trunks that reach over the edge of the reflector cup to enter and branch out in the light-cell layer (*N.*).

The fibrillar mass or rod mass (*R. M.*) is also present and well developed. The rodlets that compose it show several minor differences in the various species. Thus in *Nyctiphanes* it shows several

combinations of directions of the rods, while in *Nematocelis* it is made up of rods all lying parallel to one another in a proximo-distal direction. In *Stylochiron* the rodlets are arranged radially to form a perfect sphere.

The first new structure to be observed is a very perfect chitenous lens (*Lc.*) placed on the distal opening of the light-cell cup and against the fibrillar mass. In form this lens varies from round, as in *Euphausia gracilis*, through various lenticular shapes to irregularly flat, as in *Euphausia pellucida*. The inclination is, however, in most cases, toward a real lens-shape that will focus the light at short distance from the animal's body.

This lens has been mentioned as chitenous. Its composition has never been adequately worked out. It shows a color and staining reactions that seem to warrant one in calling it chiten. It also shows zones of fixation that make it appear that the body is of a soft or even semi-fluid condition in life. In most of the forms of Euphausidæ the cells that form the lens are easily discerned in sections as a layer of large, flattened cells with correspondingly large and flattened nuclei. In *Nyctiphanes norvegica* this layer is very hard to see and appears to have lost its cellular nature. The origin of this lens and the morphological meaning of its controlling cell-layer are very puzzling. Practically no trace of it occurs in the eye-stalk organs unless certain cells of the light-cell mass lying outside of the reflector cup and against the lamellar ring are the analgen of this structure. Or, again, we would seem to be obliged to consider the lens as the result of a secondary invagination from the outer surface, with the cells of this infolding layer secreting the chitenous material from their distal surfaces. It appears certain that the presence of this lens divided the mass of light-cells into the proximal cup of real light-producing cells and a distal mass whose staining reactions and cytoplasmic structure show a differentiation that indicate their non-participation in the light processes.

Trojan considers these cells just outside the lens to be an external layer of light-cells in *Nyctiphanes conchii*. His figure certainly shows very little difference between them and the real light-cells. In other forms, however, especially in *Nyctiphanes norvegica*, real differences appear, and one cannot but come to the conclusion in this latter case that these outer cells have become differentiated into a secondary lens or outer lens (*O. Lc.*).

In *Nyctiphanes norvegica* these cells have become arranged in a well-defined circular layer of definite thickness. At the outer edge this layer has been cut away to insert the ring of lamellar tissue (*La.*), which is still quite distinct from the reflector against which it lies. The position of this lamellar layer is very suggestive of a possible new function. Trojan and others have called it the outer reflector in the simpler organs. In its position and the direction of its lamellæ or rods in *Nyctiphanes norvegica* it strongly suggests a muscular focussing arrangement. This view can be easily proved or disproved by the proper staining and other tests to determine if the lamellæ are muscle fibrilis or not.

Outside of the secondary lens and between it and the hypodermis of the cornea comes a large blood-sinus (*Bl. S.*). The connections of this sinus and those of the strong capillaries that enter the light-cell layer have not been traced. This blood seems to be the only layer between the light-cells and the exterior that is not specialized for the transmission of light by being made transparent.

The cornea is merely a somewhat thickened portion of the hypodermis with its cuticle. It has been rendered transparent for the passage of the light. The uses of this light are somewhat obscure. But few real observations have been made, and some interesting speculations. Dr. William H. Dall, of the National Museum, has observed some Euphasid, probably *Nyctiphanes,* coming in vast swarms to the surface at night in the waters of Puget Sound in April, probably for purposes of breeding. They were lighting continuously and made a considerable luminosity in the water. Here it seems that they used their light in numerous flashes as a mating signal.

The writer has seen them swarming at the surface in much the same way, on the surface and on the shores of Passamaquoddy Bay, in Maine, in latter July and August. This species was *Nyctiphanes norvegica*, and the animals were giving out flashes that were nearly as bright as a fire-fly. Fig. 6 was drawn from descriptions of this scene. The nerves supplying the organs were evidently used to cause and control these flashes. Miss Mildred Prince has also told the writer how these fall swarms of the same animals were thrown ashore in windrows on the beaches of Campobello Island, in the same region. These masses of animals were glowing continuously, when disturbed, with a weaker light than that shown by the flashes. This abnormal lighting or

"death-glow" is characteristic of many creatures and shows a weakness or disorganization of the nervous powers.

Chun discusses the light process and shows that it might be possible that the animal uses it to see its prey or other objects, since with the abdomen flexed all of the lights would converge on the region directly in front of the creature. He also calls attention to the fact that some of the photospheria, especially the abdominal organs, are capable of being moved in an anterio-posterior direction through a considerable arc by their possessor.

The animal is not always easy to stimulate into the lighting condition. Sometimes a mere jar of the vessel of water in which they are will bring about a display. Usually, too, they light when removed from the water with the hand. At other times, however, one can jar or annoy them for a considerable time without seeing the light. When crushed or severely injured the steady "death-glow" sets in. This can also be brought about by more minute injuries to the nerve-ganglia with a needle.

We must now examine one of the lower forms of Schizopoda, *Gnathophausia calcarata,* captured by the German deep-sea expedition in 1898, at a depth of 1326 metres. This form gave off a greenish light from about the mouth region. Illig observed that, when it was thrown into a picric-acid fixative, the luminous secretion was fixed in whitish strings by the preservative action of the fluid.

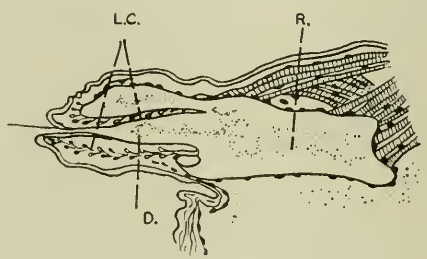
He detected the exact point from which the secretion came, and found it to be a papilla situated on the base of the exognath of the second pair of maxillæ, one on each of the pair of limbs. He cut longitudinal sections of this part and pictures the gland as seen under the microscope. Fig. 12 is copied from this drawing of Illig's.

The section shows an invagination into the body of the papillæ, passing through the length of the papillæ as a duct (*D.*) and expanding in the larger basal portion into a large, glandular reservoir (*R.*). The walls of the duct are of the same type as the external integument, a substantial hypodermis bearing a somewhat thinner cuticle. At the opening of the reservoir into the duct the cuticle is folded back, forming a peculiar, valve-like arrangement, the use of which is hard to determine. It is possibly of use in retaining the luminous fluid until the time of discharge.

The reservoir is large and of sac-like shape. A clotted sub-

stance, resembling a blood-clot in Illig's figure, occupies the interior. The wall is made of a thin layer of flat cells with flattened nuclei, the whole somewhat resembling the intima of a blood-vessel. The glands that secrete the luciferine (*L. c.*) lie in the walls of the papilla through which the light substance is ejected. But they do not open into the duct, but into a crevice in this wall that passes backward and discharges into the reservoir behind the valve-like edge of the opening from reservoir into duct. Illig has not described these glands carefully. His figure leaves one in doubt as to whether they are unicellular glands, which are almost unknown in crustaceans, or whether they are bunches of gland-cells arranged in the form of the usual integumentary

FIG. 12.



Section of the light-organ found on the base of the exognath of the second pair of maxillæ of *Gnathophausia calcarata*. *l. c.*, light-cells; *r.*, reservoir; *d.*, duct. (After Illig.)

glands of these forms. The latter seems the more natural, and further work will probably demonstrate that it is the case.

Higher Decapod Forms.

The middle depth of the ocean, from 600 metres to 2000 metres in depth and over, are the home of a large number of small- to medium-sized decapod crustaceans, called prawns in general and living a free swimming life near the bottom or suspended at these depths over much deeper bodies of water. In color they are either transparent or of a bright red, in part or in whole, while a few of them show bright-blue markings on parts of their bodies.

Many of these prawns are capable of producing light, and here we find, as in the Schizopoda, two types or perhaps three. One type with an external combustion, one with an internal combus-

tion, and a possible third in which the light-producing is a combination of these two forms.

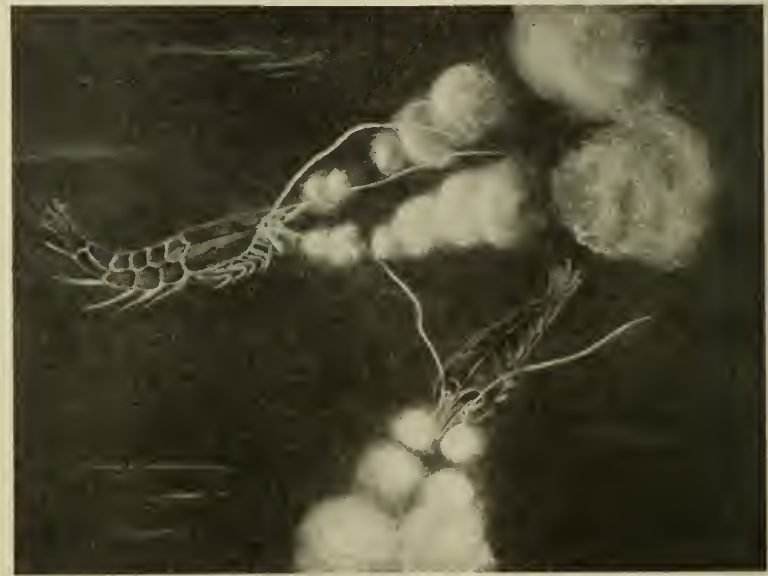
The first group of prawns consists of several known species, and in all probability a number of species yet to be determined, that, when disturbed in the water in which they live, throw out a stream of luminous substance from two points at the bases of the second pair of antennæ, as it has been described by several naturalists. Alcock mentions two such prawns, *Heterocarpus alphonsi* and *Aristeus coruscans,* both of which poured out copious clouds of a "ghostly blue light of sufficient intensity to illuminate a bucket of sea-water so that its contents were visible in the clearest detail." Alcock thought that the light came from the orifices of the nephridia or "green glands." Recently, through the kindness of Dr. H. F. Moore and Mr. W. W. Welch, of the United States Fish Commission, the writer has been given the privilege of examining some as yet unnamed species of prawns, much resembling those described by Alcock, that were taken from the waters of our eastern coast in depths of from 300 to 1000 metres. These creatures were placed in large glass jars of sea-water when brought on the vessel "*Grampus*" at night, and when disturbed they gave out the same clouds of bluish light. As in the case mentioned by Alcock, these two streams of luminous material were copious and appeared to come from the "under side of the head." Fig. 13 shows them as they appeared under these conditions.

The writer has dissected and sectioned these prawns and come to the following conclusion: The luciferine is secreted by a large number of glands of the common integumental type found in crustaceans. These glands pour out the secretion from hundreds of tiny, hair-like ducts opening on the under side of the head from around the mouth and from the inner sides of the bases of the limbs on the anterior part of the thorax. This very small amount of secretion is then mixed with the strong stream of water, augmented for the occasion, that comes from the respiratory chamber and is thus carried out in the copious clouds of light that have been described. Fig. 13 shows some of these prawns as they appear when the light is emitted. Mr. W. W. Welsh told the writer how the discharge sometimes came forth as two rings like the rings blown by a man smoking. These rings moved through the water with their vortex-momentum and ended by sticking

against the sides of the glass vessel, still ring-like, where they remained luminous for some time.

The glands (Fig. 14) consist of from three to five or seven cells (in section) placed closely together around a very small lumen that empties out through a fine, hair-like duct. This duct joins the others that come from the neighboring glands of the group and runs parallel with them, forming all together a large body of separate canals, so fine that their exact structure has not been made out. They all open separately through fine canals in the chiten of the shell.

FIG. 13.



Representation of the two prawns (like *Heterocarpus* or *Aristeus*) as they appear when lighting in the sea. (Original drawing by E. Grace White, after descriptions by Alcock and W. W. Welsh.)

The gland-cells appear to be of several different types on account of their size and the character of the contents of their cytoplasm. Each cell has a large proximal surface, forming a portion of the outer surface of the spherical gland, while its exceedingly small distal surface forms a part of the tiny lumen and fundus of the gland. The nucleus is somewhat proximal and the cytoplasm is divided into one or more zones, according to the type of the gland and the state of its activity.

First we find what the writer considers to be a young gland, either in actual age or in its cycle of secretory activity. The cytoplasm is homogeneous in color and texture, except for a striated appearance that reminds one of the muscle or of some electric tissues. This gland is very small and apparently is not secreting; it stains dark red in a Delafield-eosin preparation.

A second type is possibly the luciferine gland. It is much larger than the young gland, and its cytoplasm is composed of a

FIG. 14.

Drawing of a light-gland of a deep-sea prawn (species undetermined). Shows six cells around the lumen, dark granular secretion in cells, and the duct of this gland passing out to join a group of ducts from other neighboring glands. Ducts are only visible when the secretion is in them and is stained. (Original drawing.)

pink proximal portion and a distal portion filled with fine, deep-staining granules. Fig. 14 shows this particular kind. The extreme distal portion of the cell is more or less free of the granules and is modified by the presence of fine channels opening into the lumen, which is very small. The granules pass from the secreting zone through these canals into the lumen and thus out of the gland through the long, fine ducts. These ducts are so fine that but one granule at a time can pass into the lumen. They are only visible when occupied by a row of the granules and when the granules

are properly stained. The bundle of ducts separates considerably upon approaching the surface from which they discharge. Each separate duct passes between the hypodermal cells and opens to the exterior through a small canal through the chitenous cuticle.

Others of the glands are large, and the cytoplasm of the cells is somewhat granular but almost colorless with this stain (Delafield's hæmatoxylin and eosin). It is probable that such a gland is in some stage of secretion in which the staining power is temporarily lost. The exact relationship is not clear. The cells stain a very light pink.

A fourth kind of this gland is one in which the cytoplasm of the cells is of a homogeneous, clear-blue material that resembles mucus. Such cases are probably a mucus-gland, although the fact was not positively established. In some cases both cells of the blue (mucus) and light pink kinds were present in one and the same gland. This did not seem to indicate a transition, but rather a mixture of two kinds of cells in one gland.

While the above structures are in all probability the light-producing organs, the possibility yet remains that the nephridial glands are the real seat of the luciferase production. The production of light by a modified portion of a renal gland is known in the fly *Bolitophila luminosa,* as will be shown in a succeeding chapter. The nephridial gland of this shrimp has been examined carefully, however, and no specialization of its epithelium has been observed that would warrant such a supposition. Nor was there any clotted secretion in its lumen such as is visible in the lumen of the characteristic light-producing glands. The writer feels confident that the integumental glands as roughly described above will prove to be the seat of light production, and that the squirting action observed in the living organism will be found to be due to the action of the respiratory stream in carrying the luciferine out into the regions in front of the creature's head.

The next forms to be studied are the decapod forms as exemplified by the genus *Sergestes.* In general appearance and in habit as well as in size the species of this kind closely resemble the above forms. Dr. Stanley Kemp has worked up the forms belonging to the Natantia and finds that we know of six species that bear light-organs of the internal type, as follows:

Penæidea: Sergestes challengerii and Sergestes gloriosus.

Caridea: Acanthephyra pellucida, Acanthephyra debilis, Hoplophorus grimaldi, and Hoplophorus sp. juv.

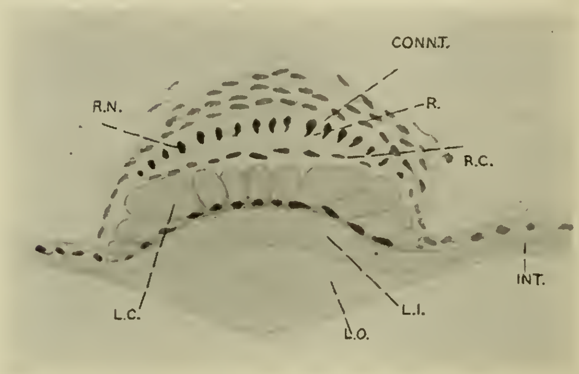
and that, further, it is probable that two other species belonging to the Penæidea, *Gennades* and *Amalopenæus,* also possess light-organs of the same general type. All these animals are very rare and are only occasionally captured by more or less expensive expeditions, and investigators should take the trouble, when so fortunate as to be on an expedition and see them caught, to observe their light powers at once in a dark room and to preserve some of them for histologic investigation in the laboratory.

Sergestes challengerii shows a great many—as many as one hundred and fifty—photophores on the surface of its body. The smaller and younger specimens show a lesser number, showing that the number increases with growth until maturity. These organs are distributed, according to Kemp, somewhat as follows: "They occur on the lower sides, on the oral appendages, on the thoracic and abdominal sterna, on the ventral surface of the outer uropods, and on many of the leg-joints. All are so situated that the light which they produce is thrown directly or obliquely downward." Some organs have been described on the lateral face of the carapace. These are not on its outer surface, but are placed on its inner surface when it is infolded, to shine downward and illuminate the gill-chamber from above. They are small and the lens varies from 0.06 mm. to 0.14 mm. in diameter. They are all practically the same in their structure, which, however, differs greatly from that of the photophores (photospheridia) of the Euphausidæ.

Figs. 15 and 16 show representations of two of these organs, Fig. 15 being a drawing of one from the penultimate joint of the second maxillipede and Fig. 16 a drawing of one of those found on the outer wall of the gill-chamber. The outer structure is a very perfect cuticular lens (*L. O.* and *L. I.*), being a thickening of the chitenous cuticle of the body. This lens is bi-convex and is composed of two layers that stain somewhat differently and represent the layers shown by other parts of the body cuticle. This modified cuticle is made very transparent, as would be expected, and it will be interesting to ascertain its index of refraction in the living of fresh state and to compute its focus as used by the animal. The chief portion of this lens-thickening is formed by the

outer layer (*L. O.*), which is bi-convex. We should also learn how this region is carried through the process of ecdysis.

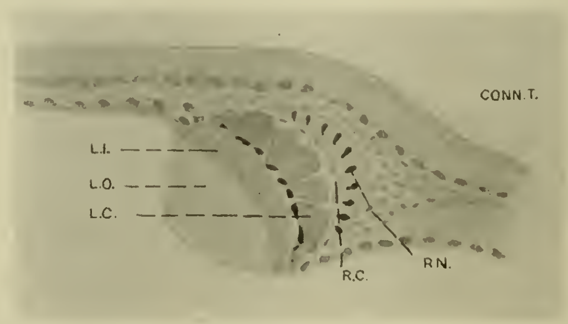
FIG. 15.



One of the larger light-organs of *Sergestes challengerii* in median vertical section. *l.o.*, outer part of lens; *l.i.*, inner layer of lens; *l.c.*, light-cells with distal nuclei; *r.c.*, reflector-cells; *r.*, reflector; *r.n.*, nuclei in reflector; *conn. t.*, connective tissue at back of organ. (After Kemp.)

The layer immediately below or proximal to the lens is obviously a modified portion of the hypodermis (*L. C.*). The cells have become very much larger, particularly their proximal

FIG. 16.



Another light-organ from *Sergestes challengerii*, found inside the gill-chamber on the integument. Lettering same as in Fig. 15. (After Kemp.)

parts, and the cytoplasm has assumed a strongly refractive, hyaline appearance that does not give any clue to their use. In properly preserved specimens as well as in fresh specimens these cells

contain a deep, transparent, blue pigment which is the cause of the blue color of the photophores in the living or freshly-dead animal. This further complicates the question. These cells are the only ones in the structure that appear to have glandular cytoplasmic bodies capable of secreting luciferine. And yet the presence of the blue pigment would indicate that they were accessory structures rather than the specific cells of the organ. And Kemp has called attention to the fact that this layer of cells also forms a lens-shaped mass which might indicate a refractive function. This idea does not appeal very strongly to the writer, who is inclined to believe that they are the light-producing cells which also serve to tinge the light with the blue color. The fact that they are apparently the only ectodermal cells in the organ also lends strength to this view.

Their nuclei occupy a very remarkable position, being situated in the extreme distal tip of each cell. Kemp describes, although he does not figure, chromosomes in these bodies. We must also consider that these cells are the only ones in direct contact with the lens, and that, therefore, they must be the cells that secrete this lens. They are, apparently, cells with at least three and possibly four functions to perform.

Just under these light cells appears a thin and unimportant appearing layer of flat, very thin cells that serve to separate the light-cells from the reflector. These flat, thin nuclei appear in the section as lines. It is not possible to assign any function to this layer until further material has been secured and more complete studies made. They will be called temporarily the reflector cells (*R. C.*).

Proximad to the flat cells appear a thick, dish-shaped layer which has been called by Hansen the reflector (*R.*). Kemp agrees with this view, and it seems reasonable to assume that such is the case. The layer is thick, as Figs. 15 and 16 show, and contains the wavy parallel strands and plates of a dense material that are found in the undoubted reflectors of the Euphausidæ and squids, as well as in the light-organs of many other organisms. A single series of pear-shaped or wedge-shaped nuclei appear in the middle level of this layer with their apices pointing outward (*R. N.*). The remarkable form of these nuclei cannot be explained, and in the other similar reflectors we find, usually, no nuclei at all. In the organ under discussion they form a graduated series, with the

larger ones in the centre and the smaller ones out toward the edge. From what we can see we must designate them as the nuclei of the reflector (*R. N.*).

Behind the reflector is found a mass of ordinary connective tissue (*Conn. T.*) weakly differentiated and organized with relation to the organ, but not taking any specific part, other than an apparently mechanical one, in its organization.

The two luminous species of *Acanthephyra, A. pellucida* and *A. debilis,* possess light-organs that show a considerable resemblance to those of *Sergestes,* but which differ from them in many details. They also differ in structure among themselves. Kemp describes their number and position in *Acanthephyra debilis* as follows: "The most highly developed organs in *Acanthephyra debilis* are not all of similar structure as they are in the case of *Sergestes,* but exist in different degrees of complexity in different parts of the animal." "The most highly developed organs are twelve in number, and each is so placed that the light which it produces is thrown directly downwards. One is situated on the distal and external aspect of the protopodite of each pleopod, and one behind the protopodite of each uropod."

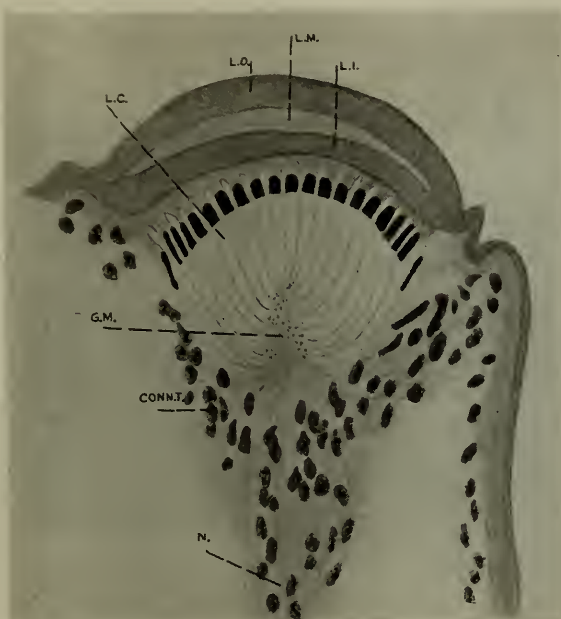
Fig. 17 is copied from Kemp's photograph of this organ. Here we see that a lens is formed, as in *Sergestes,* from the cuticle. This lens (*L. O., L. M.,* and *L. I.*) is not so thick as in *Sergestes,* and its outer surface is convex, while the inner is concave. It shows three layers instead of two, and the extra layer is a middle one. The lens measures 0.24 mm. in diameter, and its entire substance is permeated with a transparent, violet-blue pigment. The middle layer (*L. M.*) does not appear to extend into the general cuticle from which the lens is formed. At the edge of the lens the cuticle is much thinner than even the surrounding general cuticle, and is thrown into folds. This would permit of some movement of the organ as a whole if muscle apparatus is placed in a position to move it.

Inside of the lens appears the same layer of elongate cells that we find in *Sergestes.* They are much longer than in that animal and appear to radiate from a proximal centre. Their inner ends are filled with the same homogeneous and hyaline cytoplasm, and here again the writer must differ with Kemp, who implies that they form a secondary lens, by assuming that they are the gland-cells (*L. C.*) of the organ and that they secrete luciferine. The

nuclei are placed in the extreme distal tips of the cytoplasm, and, as the cells are hypodermal in origin and lie directly against the lens, they must secrete the lens as well as furnish the light. This double function may explain their peculiar structures.

The well-developed reflector of *Sergestes* is represented here by a loose, fibrous mass whose strands radiate in a proximal direc-

FIG. 17.



Median vertical section of one of the large light-organs of *Acanthephyra debilis*. *l.o.*, outer layer lens; *l.m.*, middle layer of lens; *l.i.*, inner layer of lens; *l.c.*, light-cells with distal nuclei and long proximal bodies; *g.m.*, granular mass; *conn. t.*, connective tissue; *n.*, nerve. (After Kemp.)

tion from the central point of the light-layer, where they are mingled with a mass of granular matter (*G. M.*). The nuclei that support this structure are placed in masses in an extreme proximal position. We will assume that this arrangement represents an imperfect reflector to some degree, but we must also take account of a nerve-bundle (*N.*) that approaches the photophore from its inner end and distributes its nerve-fibres through the mass of apparent connective tissues (*Conn. T.*). No suitable

methods have been applied to distinguish these nerve-fibres from the connective tissues or to see how and where they end.

This organ is quite evidently a more primitive type of the organs found on *Sergestes*. But in addition to these principal organs in *Acanthephyra* we find even simpler ones (Fig. 18). A good example of such is seen in the freshly-caught specimen as a dark-violet blue streak on each side of the inner wall of the carapace just behind the last pair of thoracic legs. When this streak of blue tissue is cut in transverse section we find that the

FIG. 18.

Transverse vertical section of the long light-organ on side of *Acanthephyra debilis*. *l.*, lens; *l.c.*, light-cells; *n.*, nerve. (After Kemp.)

color is due to a long, cylindrical lens (*L.*) that has been formed by a slight thickening of the cuticle. This lens region is tinged throughout with the blue pigment that gives the organ its external color, and it also shows a weak division into an outer and inner layer, and it has acquired the usual transparency of lens organs. It is still, however, a very weakly developed organ and cannot do much towards focussing the light.

Beneath the cuticular lens is found the usual row or layer of elongate hypodermal cells. In this case, however, they have not developed to the same extent as in the larger organs on the same animal. The nuclei of these cells do not occupy the extreme distal tips of their respective cells, but they show a strong tendency

to do so. Fig. 18 shows this, as it also shows the weak differentiation of a mass of connective-tissue cells below into an indefinite structure that in the more advanced organs becomes a reflector. Traces of a nerve supply (*N.*) are also present, according to Kemp.

In the species of *Hoplophorus grimaldi* the light-organs seem to agree very closely in structure and distribution with those just described in *Acanthephyra*. In regard to the pigmentation of the animals whose photophores have been described above, and to the meaning of these organs, we cannot do better than quote the remarks of Kemp in his excellent paper, as follows:

THE PIGMENTATION OF THE PHOTOPHORES.

"It has already been mentioned that a deep-blue pigment is, in life, associated with the photophores of Decapoda, occurring in *Sergestes* in the first cellular layer and in *Acanthephyra* in the lens itself.

"There is reason to believe that this pigment is closely allied to, if not identical with, that found in the lobster. When the photophore is placed in absolute alcohol the blue color soon becomes bright red, and the same reaction instantaneously appears when it is boiled in a drop of water. If the lens of the Acanthephyra be dissected out and treated with strong sulphuric or nitric acid the color at once changes to red, and immediately afterwards turns to a dull greenish blue of a much less distinct color than that originally present. The greenish-blue tone appears to fade away a little later, but the concluding stages of the reaction are somewhat obscured, owing to the burning of the tissue by the acid.

"The red pigment which gives the familiar coloring to *Nephrops* and to the lobster, when boiled, is known to be one of the lipochromes or fatty pigments, called by Moseley *crustaceorubin,* associated with a small quantity of yellow pigment, known as *Hepatochrome,* which appears to be derived from the liver. The investigations of Krukenberg and of Miss Newbigin seem to show that the unstable blue-black pigment or *lipochromogen* which occurs in the lobster is a compound of the red lipochrome with a complex organic base. The blue color is turned red by any reagent which alters the form of the proteid, and the red pigment, extracted and dried, gives, with strong acids, a brilliant but evanescent blue reaction.

"The photophores are, unfortunately, so minute that it is not possible to extract a solution of the pigment; but the reaction mentioned above, which was obtained by the addition of acid to the lens of *Acanthephyra,* furnishes fairly satisfactory evidence of the nature of the pigment. The following observations on the red coloring-matter of *Acanthephyra* may be mentioned here: An ether extract of the pigment gave a bright-yellow solution, which on evaporation yielded an oily red extract. On the addition of strong nitric acid a bright, but rapidly evanescent, blue reaction was obtained, which was followed by the separation of the red matter from the oily yellow pigment, the latter turning a dull green. This result is practically identical with that obtained by Miss Newbigin with the extracted pigments of *Nephrops.* The red coloring, which turns blue under the influence of the acid, is the lipochrome, *crustaceorubin,* while the oily yellow pigment is *heptochrome.* The acid breaks up the proteid and at once converts the blue *lipochromogen* into the red lipochrome, and this is immediately followed by the characteristic blue reaction which this pigment gives in the presence of an acid. The tissues burn and become brown under the influence of the reagent, and the rapid evanescence of the blue tint, which is characteristic in the case of dry extracted pigment, is in consequence, somewhat masked.

"It has not been possible to test the blue pigment in the photophores of *Sergestes* as fully as has been done in the case of *Acanthephyra,* but from the fact that it turns red when boiled or when treated with strong acids it is very probable that it is of the same nature.

"The existence of blue coloration in deep-sea animals is exceedingly rare, and its occurrence among Decapoda in close association with the photophores is almost unique, for among the Euphausiacea a similar pigment appears to have been noticed only on a single occasion. In November, 1909, a large specimen of *Thysanopoda acutifrons,* Holt and Tatterstall, was caught in a mid-water net off the west coast of Ireland. This specimen, which was dead by the time it reached the deck, was found to possess patches of deep-blue pigment associated with the photophores on the eye-stalks. Casual examination failed to reveal this pigment in the other photophores, which, however, were of a darker color than is usually the case. The specimen was put aside in a dish of water, and when it was again examined, not more than half an

hour later, all trace of the blue pigment had vanished. It is evident that, even if in this case the blue coloring invariably occurs in the photophores, the phenomenon is one of great rarity among Euphausians, for it certainly is not found in *Meganyctiphanes norvegica* or in any of the common North Atlantic species.

"The blue pigment of the photophores of Decapoda is much more stable than that noticed in *T. acutifrons*. Although rapidly extracted by alcohol, it will persist for years in specimens preserved in weak formalin, remaining distinct long after the general red coloring has disappeared.

"The lens of *Acanthephyra*, being blue, can necessarily only allow the emission of blue light, and it is not impossible that this is also true in the case of *Sergestes*, where the lens is transparent and the first cellular layer blue. It seems then that, at least in the former genus, the production of blue light is a necessity, but it is impossible to suggest any explanation of this curious phenomenon.

"Photophores have evidently been developed by crustacea in at least three separate instances. Those possessed by *Acanthephyra* and *Hoplophorus* are in structure wholly distinct from those of *Sergestes*, while in neither case is there any resemblance to the very complex organs of the Euphausiacea.

"It is a remarkable fact that, whereas in the latter order the possession of photophores in the general rule (only in *Bentheuphausia* are they absent), their occurrence in large genera, such as *Sergestes* and *Acanthephyra*, is limited to a few species only. This is particularly noteworthy in *Sergestes*, in which two forms, both of which are classed among a small group of extremely closely allied species, exhibit a large number of photophores, whereas none are to be found in the other members composing the group.

Döflein, in a short but interesting paper, has summarized the various suggestions which have been made as to the use of luminous organs to marine animals. He remarks that they probably serve different functions in different groups of animals, and classes them in four sections:

"I. Attraction of prey (chiefly important in sessile or slowly moving animals).

"II. Attraction of other individuals of the same species, either (*a*) for the formation and maintenance of swarms or (*b*) to

enable the sexes to find and recognize one another. In this connection Döflein points out that animals with a complicated system of photophores always possess highly developed eyes, and refers to Brauer's theory that the varying arrangement of photophores produces light patterns serving as recognition marks, like the color-patterns of animals living in daylight.

"III. Protection. The clouds of luminous secretion emitted by some species may possibly serve the same purpose as the ink of the cuttlefish, and photophores may also, by a sudden flash of light, scare a pursuer. In the fauna of land and shallow water a brilliant coloring is often assumed as a signal that the species is distasteful, and some deep-sea animals may, for the same purpose, exhibit warning lights.

"IV. Illumination of objects viewed by the animal. On this theory it is difficult to account for the ventral and lateral position of the photophores in many marine animals. In Crustacea this is particularly well shown, for the large majority of the organs illuminate regions which seem altogether out of range of the eyesight.

"It is evident that these suggestions will not account for every case which can be found; the photophores in the roof of the branchial chamber of *Sergestes* remain inexplicable.

"The vast majority of marine animals which possess photophores live at the surface or at intermediate depths and never occur on the bottom. No exceptions to this rule have been noticed in the deep-water fauna of the Irish Atlantic slope, but it seems that the two Euphausians, *Meganyctiphanes norvegica* and *Nyctiphanes couchii*, are sometimes found on the bottom in shallow water. On one or two occasions large numbers of these two species have been caught off the Irish coast at depths of forty to sixty fathoms, and there are indications that the specimens which were obtained in these hauls were actually living on the sea-floor. The same two species are frequently obtained over depths of 400 to 800 fathoms off the west coast of Ireland, and here they invariably occur in midwater.

"It must be remembered that the ordinary open-mouthed nets, which are generally employed for bottom work, frequently catch midwater organisms while being hauled, and there is reason to believe that errors arising from this source exist in many of the instances in which animals bearing photophores have been recorded from the bottom.

"Many of the higher marine animals live on the sea-floor at depths to which no ray of sunlight can ever penetrate, and, though they possess well-developed eyes, are themselves, for the most part, without any special illuminating apparatus. That light exists at these depths seems almost certain. It is probably fairly plentiful in regions thickly populated by Cœlenterates, and the excretions of numerous animals of a more highly organized nature have been found to be brilliantly phosphorescent. The restriction of photophores to species living in midwater seems only explicable on the theory that there is a comparatively plentiful supply of light on the bottom itself."

There are other kinds of Crustacea that also produce light. Unfortunately we have but meagre descriptions. Two of the most interesting of these are the large spider crab, *Colossendeis gigas,* and the shrimp, *Pentacheles phosphorus,* both of which were dredged from the depths of the Indian Ocean by Alcock on the research ship *Investigator.*

The spider crab, which was very large, showed a greenish-blue light radiating from the ventral surface of all of its legs. The shrimp show two points of light glowing with a steady radiance from each side of the openings of the oviducts. In daylight these points could be seen as glandular patches of a greasy texture. We have no further information on this subject.

(*To be continued*)

Potash in Lake Muds of Western Utah. Anon. (*U. S. Geological Survey Press Bulletin* No. 271, May, 1916.)—Potash in surprisingly large proportions is present in the brines and muds of the Salduro Marsh, a sink in the Salt Lake Desert, about 60 miles west of the southwest edge of Great Salt Lake. From the clays underlying the salt body which covers the marsh the United States Geological Survey collected samples at depths of 8 to 12 feet, in which the dissolved salts were found to contain from 2 to about 3½ per cent. of potash, and 2¼ per cent. was found in the soluble salts at a depth of about 4 feet. Of the dissolved salts contained in the brines occupying the spaces between the salt crystals in the crust overlying these muds 3 to 4 per cent. was found to be potash.

Singularly enough, the salt crust left at the surface of the desert through the evaporation of the brines contains little more than a trace of potash, most of the potash being confined to the brines and to the muds underlying the salt crust. The successful extraction of this potash is a fascinating as well as most pressing problem for the chemical engineer. According to analyses made by the Survey,

the brines and muds from the Salduro Marsh contain considerable magnesium chloride, as well as chlorides of potassium and sodium, and so are somewhat similar in composition to the deposits from which potash is manufactured in Germany. Therefore, it appears that success in methods for manufacturing potash at the Salduro Marsh should prove comparatively easy. While no extensive exploratory work has been done by the Survey to show the area of the deposit, it is believed that the amount of potash present in the region, if it can be extracted with commercial success, is sufficient to provide a valuable source of supply to the country.

The Origin of Lightning. ANON. (*Electrical Review,* vol. 68, No. 20, May 13, 1916.)—Various theories have been presented from time to time to account for the electrical charges which are accumulated by clouds, many of which have been widely discussed. Lightning phenomena are usually accompanied by heavy downpours of rain. It is well understood how the voltage of a cloud may be raised by the combination of many fine charged particles of moisture into drops which are large enough to be precipitated to the earth. The large drop carries the combined charges of all the small drops which go to make it up, but its surface is very much less than the combined surfaces of the component droplets; hence the surface density of the electrical charge is very much greater. When the drop is large enough to fall and approaches the earth, the voltage may be high enough to cause an electrical discharge across the intervening space. But how are the original charges upon the tiny moisture particles produced?

The most plausible explanation for this has been advanced by Dr. George Simpson, who proved that when drops of water are broken up they become charged positively, while the surrounding air receives a negative charge. A thunder cloud is known to form in a rapidly ascending current of air, and if the velocity is as great as 26 feet per second, the smaller drops will be carried upward, while even the largest drops will be unable to progress against the current. The larger drops break up in the air and become electrified, according to Doctor Simpson. If the ascending current spreads out laterally near the top of the cloud, the vertical velocity is diminished, the drops will grow and fall, but only to break again and repeat the process. Sufficient electricity might be thus accumulated to account for the observed effects.

The rain which reaches the earth is sometimes charged positively and sometimes negatively, but more often positively, which is in accord with the above idea. This does not account for the fact that the earth as a whole is negatively charged, although local portions are at times positively electrified. There is still a great deal to be learned in connection with atmospheric electricity, but Doctor Simpson's hypothesis seems to offer an adequate explanation for the existence of thunder clouds and to be free from objections of a theoretical nature.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PLASTIC FLOW.[1]

By Eugene C. Bingham.

EXPERIMENTS by Bingham and Durham[2] showed that the fluidity of a suspension is a linear function of the concentration. The zero of fluidity is reached at a comparatively low volume-concentration, as is shown in Fig. 1. The concentration which has zero fluidity serves to sharply demarcate viscous from plastic flow. All concentrations of solid less than this are viscous, and any shearing force—no matter how small—will produce permanent deformation, if long enough exerted. Concentrations greater than this are plastic, and it is necessary to use a shearing force of finite magnitude in order to produce a permanent deformation. The laws of plastic flow have never been studied.

The method of attack was to force suspensions of clay and water, under known pressure, through capillaries of different dimensions, and to measure the rate of flow. Some of the values obtained are shown in Fig. 2. For medium pressures the volume of flow per second is given by the formula

$$v = K\ (P - f)$$

where P is the pressure employed and f is the so-called "friction"; *i.e.*, the force required to start the flow.

Putting $P - f$ in place of P in the ordinary Poiseuille formula for calculating the fluidity, we have a means for calculating the "mobility" of plastic substances, analogous to the fluidity of viscous substances.

The friction increases as a linear function of the concentration of solid present (see Fig. 1). It is independent of the length and diameter of the capillary as well as the viscosity of the medium. It is, however, affected by the presence of alkalies or acids in the medium.

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* Communicated by the Director.

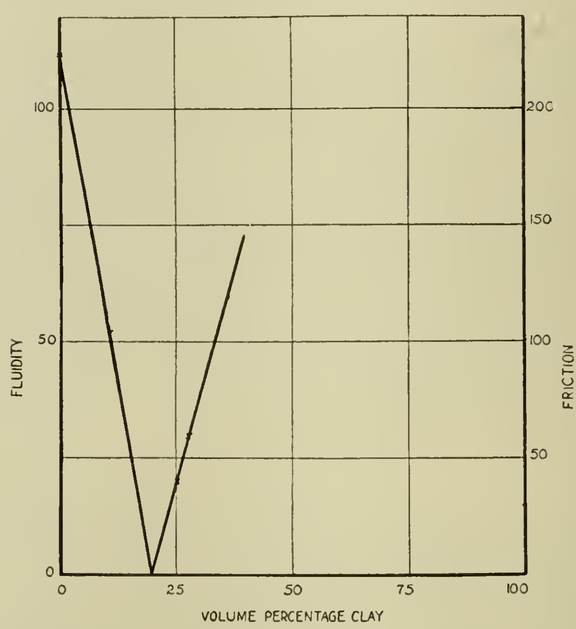
[1] Scientific Paper No. 278.

[2] *Am. Chem. Journal*, 46, 278 (1911).

The mobility decreases rapidly as the concentration of solid is increased, as is seen in Fig. 3. The mobility is also enormously sensitive to the presence of alkalies or acids, the mobility of a 50 per cent. by weight clay suspension being increased 330 per cent. by the addition of 0.1 per cent. of potassium carbonate.

At pressures little if any greater than those necessary to overcome the friction there was detected seepage of the medium past the solid particles (see Capillary 6.1 Fig. 2). At high pressures

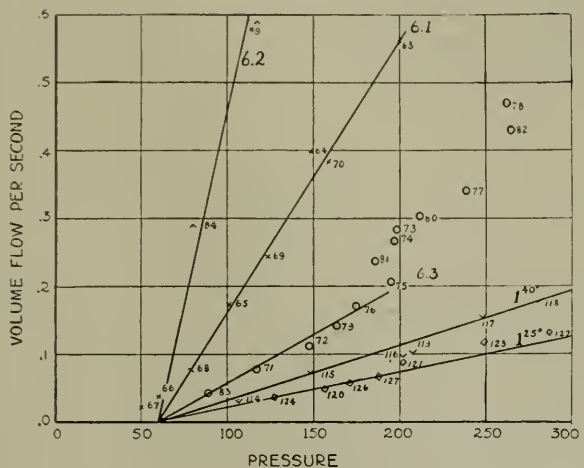
Fig. 1.



there was sometimes a sudden increase in the rate of flow, which is apparently due to slipping (see Capillary 6.3, Fig. 2).

If the solid material consisted of spheres of equal size, the pore space remaining when the particles were as closely packed as possible would amount to 26 per cent., and quite irrespective of the radius of the spheres. However, due to the friction of the spheres on each other, the pore space may be much larger than this, and this is particularly true if the material is very finely divided. As a matter of fact, it was found that on shaking dry clay into a flask, the pore space remaining amounted to 81.6 per cent. of the

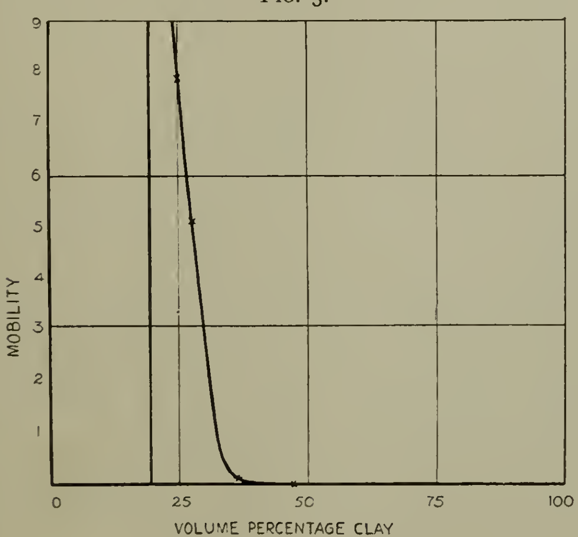
FIG. 2.



The flow (in c.c.) of 50 per cent. clay suspension in water containing 0.1 per cent. of potassium carbonate in solution, for pressures (g. per sq. cm.) as shown, and at 25° C., except one series of experiments with Capillary No. 1, which was made at 40° C. The capillaries had the following dimensions:

Capillary	Radius in cm.	Length in cm.
1	0.02848	2.468
6.1	0.05785	5.011
6.2	0.05811	2.509
6.3	0.05850	9.998

FIG. 3.



total volume. This corresponds closely to the percentage of liquid present in the mixture having zero fluidity, which is 80.5. It is upon this friction that the plasticity depends, and the plasticity is thus closely related to the fineness of subdivision of the material.

FURTHER EXPERIMENTS ON THE VOLATILIZATION OF PLATINUM.*

By G. K. Burgess and R. G. Waltenberg.

This is a continuation of an investigation undertaken at the suggestion of the Committee on "Quality of Platinum Utensils" of the American Chemical Society. Seven platinum crucibles of various makes and purity have been subjected to successive heatings at 700, 1000, and 1200° C., followed by determination of iron and other materials soluble in 1 : 4 boiling hydrochloric acid. Among the results obtained are the following:

1. Platinum ware in the form of crucibles of whatever degree of purity behaves, with respect to gain or loss of weight, on heating in air at ordinary atmospheric pressure, in a manner characteristic only of the temperature of heating.

2. Each impurity, as iridium, rhodium, or iron, appears to exert its effect on the volatilization of platinum independently.

3. For platinum crucibles of all degrees of purity containing Ir, Rh, Fe, Si (up to a content of at least 3.0 per cent. Ir) the loss on heating is negligible below about 900° C.

4. Below this temperature there may even be a slight gain in weight on heating platinum, owing to the iron content diffusing to the surface and oxidizing. At higher temperatures the presence of iron will lower the volatilization loss by amounts depending on the quantity of iron present. There appears to be no platinum made which does not contain some iron.

5. The volatilization of platinum containing rhodium is less than that of pure platinum at all temperatures above 900° C.

6. The volatilization of platinum containing iridium is, above 900° C., very much greater than that of pure platinum, and increases with the Ir content and with temperature.

7. It appears to make no material difference in the volatilization results, in the range 700° to 1200° C., what is the order of heating, ascending or descending temperatures.

* Scientific Paper No. 280.

8. In an oxidizing atmosphere at temperatures of the order of 1000° C. platinum, in the presence of, but not in contact with, silica, will apparently take up small quantities of this substance.

9. The loss in crucible weight due to the solution of soluble matter in HCl, after heating, is variable, depending on the crucible, and may be large. This loss is relatively greater at low than at high temperatures.

10. All of the above losses, caused by heating, acid treatment, and iron diffusion, apparently continue with undiminished magnitude after the first treatment, which is usually erratic.

11. The following table gives the approximate changes in weight to be expected for heating platinum containing iridium or rhodium, but nearly free from iron. The presence of iron in appreciable quantities renders the prediction uncertain, but it always acts in the direction of lowering the volatilization loss. Silica, if taken up from the furnace, will also tend to lower the results slightly.

Approximate loss in mg./100 cm.^{2}/hour at temperatures indicated for platinum nearly free from iron.

Platinum containing	Pure Pt	1 per cent. Ir	2.5 per cent Ir	8 per cent. Rh
900 or less	0	0	0	0
1000	0.08	0.30	0.57	0.07
1200	0.81	1.2	2.5	0.54

DISTRIBUTION OF ENERGY IN THE VISIBLE SPECTRUM OF AN ACETYLENE FLAME.*

By W. W. Coblentz and W. B. Emerson.

Data on the distribution of energy in the visible spectrum of a standard source of light are frequently needed in connection with investigations in physiology, in psychology, and in physics; especially in photo-electric work, in photography, and in the photometry of faint light sources. Frequent requests for such data have come to this Bureau. The acetylene flame appears to be a promising source of light, having a high intensity and a white color. The present paper gives data on the distribution of energy in the visible spectrum of a cylindrical acetylene flame, operated under specified conditions.

* Scientific Paper No. 279.

In the region of the spectrum extending from the yellow to the violet, the spectral energy distribution of all the flames examined appears to be the same, within the limits of observation. On the other hand, in the region of the spectrum extending from the red toward the long wave-lengths the emissivity is greatly affected by variation in thickness of the radiating layer of incandescent particles in the flame. Hence in and beyond the red part of the spectrum the data apply only to cylindrical flames which are operated under specified conditions.

FURTHER DATA ON THE OXIDATION OF AUTOMOBILE CYLINDER OILS.*

By C. E. Waters.

In continuation of work already published by the Bureau of Standards, as well as in the *Journal of Industrial and Engineering Chemistry,* a study was made of the rate of oxidation of three automobile cylinder oils when exposed to sunlight and air. This was done by determining the increase in weight and in acidity at intervals during a period of 438 hours' exposure. The accompanying changes in the carbonization values were also determined. The general result was that there is a gradual lessening of the rate at which the weight increases, and at the same time the formation of acid and the carbonization value increase more and more rapidly.

The Maumene numbers of the oils increased greatly as a result of oxidation, while there was a marked drop in the iodine numbers. After oxidation the oils showed a much greater tendency than before to emulsify when agitated with water. Filtration through animal charcoal removed, to a certain extent, the substances that caused this tendency, and that raised the carbonization values.

When the three oils used in the work above, and eight others, were heated to 250° C. for periods ranging from one to seven hours, the formation of carbonized matter proceeded at a rapidly increasing rate. The same was true of the eleven oils when heated for three hours at various temperatures from 230° to 280° C. It was found that in both cases the greater the carbonization value at first, the more rapidly did it increase as the tempera-

* Technologic Paper No. 73.

ture was raised or the time of heating extended. In other words, an oil which had a low carbonization value if heated to 250° for two or three hours, and an oil showing a somewhat higher value under the same conditions, will be further and further apart as the conditions become more strenuous. This being so, it is unnecessary to greatly prolong the time of heating in routine testing.

The need of extreme care in taking and preserving samples, as well as in testing them, was emphasized, because the presence of rust particles or other extraneous matter increases the amount of carbonization.

In conclusion it is shown that the carbonization value is independent of the flash- and fire-points and of the evaporation loss on heating.

AN INTERLABORATORY PHOTOMETRIC COMPARISON OF GLASS SCREENS AND OF TUNGSTEN LAMPS, INVOLVING COLOR DIFFERENCES.*

By G. W. Middlekauff and J. F. Skogland.

In 1911 the Bureau of Standards and the National Physical Laboratory of England, in coöperation, established groups of 1.5-wpc. tungsten standards, using Lummer-Brodhun contrast photometers in stepping from corresponding groups of 4-wpc. carbon standards. Although the agreement between the two laboratories was very satisfactory and subsequent measurements of the new standards at the Bureau checked the original values, it was realized, in view of the small number of observers in each laboratory, that if other groups of observers had made the measurements or if some other photometric method had been used the results *might* have been different.

Therefore, in order to obtain information as to the agreement which might be reasonably expected among different groups of experienced observers working by the same and by different methods, the Bureau invited the Nela Research Laboratory, the Electrical Testing Laboratories, and the Physical Laboratory of the United Gas Improvement Company to coöperate in an intercomparison of photometric measurements of blue-glass screens and tungsten lamps involving color differences such as

* Scientific Paper No. 277.

were encountered in the establishment of the new standards. The first two laboratories, like the Bureau, used Lummer-Brodhun contrast photometers, while the third used a special flicker photometer, and in no laboratory were the screens and lamps measured at the same time.

The results of the intercomparison show that each observer, regardless of the kind of photometer used, maintained a fairly definite criterion with respect to the mean of his laboratory, and that each laboratory likewise consistently maintained its relation to the mean of all, as judged from the measurements on the screens and those made on the lamps some months afterwards.

Considering the difficulties involved in the measurements, the different characteristics of observers, and the wide difference in illumination employed, the agreement among the laboratories was remarkably good. It is true, however, that although the differences are small they are not negligible in precision photometry. It is evident, therefore, that measurements to establish standards involving color difference should be left as much as possible to the standardizing laboratory, where the observers must be carefully selected and a considerable number employed, and the kinds of instruments and other conditions definitely fixed.

An examination of the Bureau's observers who took part in this intercomparison and who were included in a group of 114 observers tested at the Bureau by Crittenden and Richtmyer, using a special flicker photometer, shows that their mean characteristic is very approximately the same as that of the average of the 114.

Furthermore, the flicker values found in this intercomparison and also by Crittenden and Richtmyer for the tungsten lamps at 1.5 wpc. are in agreement with the Bureau's values. Hence it is concluded that the values which were originally assigned to the new 1.5-wpc. tungsten standards as a result of the intercomparison with the National Physical Laboratory can be considered as average eye values.

NOTES FROM NELA RESEARCH LABORATORY.*

NOTES ON FLICKER PHOTOMETRY: FLICKER-PHOTOMETER FREQUENCY AS A FUNCTION OF THE COLOR OF THE STANDARD, AND OF THE MEASURED, LIGHT.

By Leonard T. Troland.

THE *flicker-photometer frequency* of any two visual stimuli may be defined as the rate of alternation (cycles per second, with equal intervals) of the two in the same photometric field, which is just sufficiently rapid to eliminate flicker, when the ratio of their intensities is such as to give a minimum of flicker at a slightly lower rate.

The measurements recorded below were made with an instrument of the Whitman disk type, operated by an adjustable speed synchronous motor. The field was an annulus, of 0.23 degrees internal and 1.14 degrees external diameter, so that stimulation was strictly foveal. This was viewed in dark surroundings, and each setting was made after approximately 30 seconds' fixation of the central dark area, thus insuring fairly stable local adaptation. The artificial pupil employed was a square, 2.51 mm. on a side. Care was taken to reduce scattered light in the spectrometer system to a minimum.

Two series of measurements were taken with sixteen spectral colors, and a "physiological white" standard, of constant intensity for each series. This standard consisted of tungsten light corrected with a blue glass, so as to exhibit no chromatic tinge either when viewed directly or in the after-image reaction produced by dimming the light upon a retinal area already strongly "fatigued" by it (Hering's test for a physiological white). All of the spectral colors were equated in brightness to the standard, by the criterion of flicker, as a part of each measurement. The results for the two intensities of 1025 and 547 photons,[1] respectively, are given in the first two columns of the table below.

* Communicated by the Director.

[1] One *photon* is an illumination of the retina corresponding with a stimulus-surface brightness of one candle per square metre, and an effective pupillary area of one square millimetre.

Color	Wave-length in $\mu\mu$	Flicker-photometer frequency cycles per second							
		White standard				Plain tungsten standard, 510 photons	A.D.	Over-corrected tungsten standard, 510 photons	A.D.
		1025 photons	A.D.	547 photons	A.D.				
Red	648.2–720.0	27.76	.18	24.69	.26	.....	...	.....	...
Red	693.9–720.0	.....	...	.....	...	23.57	.05	24.63	.14
Red	676.4–700.0	28.15	.08	24.79	.17	23.82	.14	24.04	.20
Red	658.6–680.0	27.93	.14	24.34	.09	23.88	.11	23.83	.26
Red-orange	640.7–660.0	27.54	.09	23.86	.05	23.22	.10	23.60	.20
Orange	629.4–640.0	26.70	.10	23.62	.08	22.57	.10	23.19	.23
Orange	610.4–620.0	24.02	.17	22.50	.26	20.68	.24	21.57	.26
Yellow	591.5–600.0	20.26	.40	19.54	.09	16.14	.09	18.15	.14
Yellow	572.3–580.0	17.10	.35	15.94	.15	17.34	.006	17.02	.23
Yellow-green	553.1–560.0	17.82	.14	17.83	.10	18.33	.24	16.51	.32
Yellow-green	533.8–540.0	19.07	.26	18.30	.05	18.03	.08	17.66	.18
Green	514.5–520.0	21.79	.18	18.86	.15	19.90	.20	18.67	.10
Blue-green	492.1–500.0	22.49	.29	21.98	.15	21.94	.10	21.93	.21
Blue	473.1–480.0	25.26	.14	22.46	.26	23.18	.17	23.00	.06
Blue	444.0–460.0	26.13	.07	23.12	.12	24.22	.11	23.88	.13
Violet	426.7–440.0	25.76	.15	22.99	.07	23.61	.04	23.53	.10
Violet	408.1–420.0	24.13	.19	21.73	.44	22.61	.21	22.02	.11

As will be seen from the table, the flicker-photometer frequency for a white standard varies radically with the spectral character of the measured light, being greater at the ends of the spectrum than in the middle, with a minimum at about $575\mu\mu$. Similar results appear in the rougher data of Ives, who used uncorrected " carbon " light. In order to test the hypothesis that the position of the minimum was determined by a subliminal chromatic factor in the standard, very careful comparative measurements were made with two standards of equal brightness—510 photons—but of different color, one being plain tungsten light at low efficiency (having a definite orange tinge) and the other being an over-corrected tungsten light (decidedly bluish, and of about the same saturation as the plain tungsten). The results are shown in the third and fourth columns of the table. They prove that the flicker-photometer frequency is determined primarily by the character of the spectral stimuli, in relation to white, although a marked color tone in the standard will shift the position of the minimum.

Each value in the first two columns represents 4 independent determinations, except in a few cases, where 8 were taken. The values in the third column are averages of at least 10 determinations, and those in the fourth column of at least 15 determinations, in each case. The deviation measures are those of the averages.

No influence of the color of the standard upon the intensity required for a match was apparent within the limits of reliability of the measurements. The photometric sensibility, however, was found to depend on the color of the standard, and also on that of the measured light. The sensibility was exceedingly low in the red, as shown by the following table:

Color	Wave-length	Average percentage deviation in photometric brightness for a match: Plain tungsten standard	Bluish standard
Red	693.9–720.0	4.45	6.39
Orange-Red ...	640.7–660.0	4.43	6.70
Yellow	572.3–580.0	0.89	1.83
Blue-Green	492.1–500.0	1.65	2.05
Violet	408.1–420.0	0.99	2.07

All of the above results are for the writer's right eye. The investigation is being continued, and a more detailed description of the conditions will be given in a later, extended account.

Nela Research Laboratory,
National Lamp Works of General Electric Company,
Nela Park, Cleveland, Ohio,
May 18, 1916.

THE LAWS OF VISUAL MINUTHESIS: THE INFLUENCE OF INTENSITY ON THE EQUALITY TIME-FUNCTION.

By Leonard T. Troland.

THE time, t_q, required for a fresh negative after-image, projected on a reacting field of light, to just fall below the threshold may be called the *equality-time,* since it is the time needed for two differentially minuthetized ("fatigued") retinal areas to reach sensibly equal degrees of adaptation. The after-image must be produced by preëxposure of the eye to a primary stimulus during an interval t_p, the preëxposure-time, which immediately precedes the interval t_q. The function, $t_q = f(t_p)$, may be called the *equality-time function,* which is shown by experiment to be representable by a curve of the saturation type.

Measurements were made to determine the influence of stimulus intensity upon this function, the primary and the reacting lights being of the same color and brightness. The field was circular, with an angular diameter of 3.38 degrees, was provided with a central fixation point, and had dark surroundings. The initial minuthesis was produced by exposure either of the right or

left half of the field, and during the "equality period" the resulting after-image was projected on the full circle so as to occupy its original position on the field. A circular artificial pupil of 2.36 mm. diameter was employed, but the intensities, given in the table, are expressed in *photons; i.e.,* in candles per square metre for an effective pupillary area of one square millimetre. The intensity measurements were made by flicker photometry. Five minutes' dark adaptation was allowed before beginning a series of observations.

I. Results for Red: 673.5–760.0 $\mu\mu$

Intensity in photons	Equality-time, t_p (in seconds), for a preëxposure-time, t_p, of 4 seconds	A.D.	32 seconds	A.D.	128 seconds	A.D.	256 seconds	A.D.
3.89	7.38	0.49	42.3	2.2	62.9	2.4	68.3	3.4
19.45	16.1	1.0	57.4	2.2	89.1	3.5	102.2	2.6
97.2	10.64	0.43	54.3	2.4	93.3	2.0	124.8	4.7
486.0	19.3	1.4	56.8	3.0	114.7	5.3	121.5	3.1
2430.0	16.9	1.5	76.4	5.3	118.8	4.3	141.7	6.0

II. Results for Green: 516.1–525.4 $\mu\mu$

3.89	11.44	0.70	42.1	3.5	73.7	2.1	77.6	3.9
19.45	13.7	1.7	73.8	3.2	88.7	2.2	116.9	3.5
97.2	17.38	0.63	68.3	2.7	115.5	1.4	125.4	5.0
486.0	16.08	0.62	64.6	2.3	104.8	2.7	122.9	4.0
2430.0	18.2	2.00	52.1	2.6	106.6	3.1	121.1	4.4

Each of the above values is the average of ten independent measurements, and the deviation measures are those of the averages themselves. Each intensity is five times the immediately preceding one, and the highest corresponded to an external brightness of 500 candles per square metre.

An examination of the table shows that above 100 photons the equality-time function is almost independent of the absolute intensity, although there is a general tendency for the value of t_q, for a given magnitude of t_p, to increase slightly with intensity increase. The table also reveals the relative independence of the function with respect to the color of the stimulus.

The above results are for the author's two eyes, the right and left eyes being employed an equal number of times. A brief series with another subject showed similar relationships.

Nela Research Laboratory,
National Lamp Works of General Electric Company,
Nela Park, Cleveland, Ohio,
May 18, 1916.

THE THERMAL EXPANSION OF TUNGSTEN AT INCANDESCENT TEMPERATURES.

By A. G. Worthing.

THE measurements of the change in length with temperature were made on straight tungsten filaments of large cross-section. The positions selected on the filaments were sufficiently removed from the lead-in junctions so that their cooling effects were negligible. Using the temperature scale previously reported,[1] the results obtained for the region 1200° K. to 2700° K. are given very closely by the following formula:

$$\frac{L-L_{300}}{L_{300}} = 4.49 \times 10^{-6}\,(T-300) + 2.4 \times 10^{-13}\,(T-300)^3,$$

where L represents the length at a temperature T and L_{300} the length at 300° K.

The formula represents also the single value at room temperature (300° K.). The region between room temperature and 1200° K. will be included in the final publication.

Nela Research Laboratory,
National Lamp Works of General Electric Company,
Nela Park, Cleveland, Ohio.

Radium Never Seen in Nature. ANON. (*U. S. Geological Survey Press Bulletin,* No. 267, April, 1916.)—Radium is a metal and is described as having a white metallic lustre. It has been isolated only once or twice, and few people have seen it. Radium is ordinarily obtained from its ores in the form of hydrous sulphate, chloride, or bromide, and it is in the form of these salts that it is usually sold and used. These are all white or nearly white substances, whose appearance is no more remarkable than common salt or baking powder. Radium is found in Nature in such exceedingly small quantities that it is never visible even when the material is examined with a microscope. Ordinarily radium ore carries only a small fraction of a grain per ton of material, and radium will never be found in large quantity, because it is formed by the decay of uranium, a process which is wonderfully slow, and radium itself decays and changes to other elements so rapidly that it is impossible for it to accumulate naturally in visible masses. Minerals that carry radium, however, are fairly easy to determine. One of them, pitchblende, as generally found, is a black mineral about as heavy as ordinary iron, but much softer. The principal radium mineral, carnotite, has a bright canary-yellow color, and is generally powdery. There are other radium-bearing minerals of less importance.

[1] JOURNAL OF THE FRANKLIN INSTITUTE, 181, p. 417, 1916; *Phys. Rev.*, ii, 7, p. 497, 1916.

Centennial of the Coast Survey. ANON. (*Scientific American*, vol. cxiv, No. 17, April 22, 1916.)—Those who are inclined to think that the broad and valuable scientific work carried on at Washington under the auspices of the National Government is a modern development will be interested to learn that the United States Coast Geodetic Survey celebrated, on April 5 and 6, the centennial of its establishment. Even in the early days of the nineteenth century, when the shore line of the United States was far less than to-day, the importance of an accurate knowledge of the coast was appreciated, and accordingly Congress, in 1807, authorized the establishment of a National Coast Survey. A plan was submitted by Ferdinand B. Hassler, a Swiss engineer who had emigrated to the United States in 1805 and had been acting professor of mathematics at the United States Military Academy and professor at Union College. This plan was not put into effect until 1811, and actual field work was not begun until 1816. Unfortunately, the importance of surveying newly-acquired territory on state lines and fixing boundaries by permanent marks, after these positions had been determined astronomically, has not always been realized. Frequently difficulties would have been avoided, the settlement of which involved a financial outlay far greater than would have been required for the adequate support of the Coast Survey.

The actual geographic work of the United States Coast Survey is based on a system of main and secondary triangulation which covers the entire United States. On the Atlantic Seaboard the Survey has carried out a complete scheme of primary triangulation, while a second extensive system of triangulation extends across the continent along the 39th parallel of latitude and connects the surveys of the two coasts, furnishing a basis for the surveys of the thirteen states through which it passes. Other triangulation systems have been extended throughout the United States and expanded in various individual states. From the primary and secondary triangulations a tertiary triangulation has been developed along the entire Atlantic and Gulf coasts and Porto Rico, and the Pacific coast, except Alaska, where work is still in progress, as is also the case in the Philippines. The astronomical positions of the various points on the systems of triangulation have been determined by the use of the zenith telescope for latitude and the telegraph for longitude. The familiar charts issued by the United States Government show hydrographic data, including all harbors, channels, buoys, etc., as well as the topography for a few miles inland, and, in the case of rivers and other indentations, to the head of tidewater. Deep-sea soundings are made and tidal records are compiled and published. Terrestrial magnetism is another field in which the operations of the Survey have been carried on, and the study of the force of gravity has been the subject of a number of important investigations. Lines of precise levels cover the United States in a network in which the Coast Survey has coöperated with other government agencies and several railways, and the prosecution of this work is from year to year becoming increasingly important.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE BRITTLENESS OF ANNEALED COPPER.

By W. E. Ruder.[1]

EXPERIMENTS upon the effect of the more common gases for regular and deoxidized copper showed that the brittleness often developed by heating and frequently ascribed to burning is in reality due to deoxidation. With ordinary commercial copper serious brittleness begins to appear at 400° C. in dry and 600° in wet hydrogen, at 800 to 850° in carbon monoxide, and at 700° in steam. Copper previously deoxidized by the addition of boron remains unaffected at all temperatures in a reducing atmosphere. The brittleness is, therefore, probably due to the reduction of the cuprous oxide around the primary copper grains, leaving a spongy mass with little mechanical strength.

The Electrical Capacity of Gold-leaf Electroscopes. T. BARRATT. (*Proceedings of the Physical Society of London,* vol. xxviii, part iii, April 15, 1916.)—The modern gold-leaf electroscope has for some considerable time been employed by workers in radio-activity as an instrument of precision comparable with that of other instruments used in electrical measurements. Many workers in other branches of physics, however, still appear to regard the instrument as merely of historical interest. It is the experience of the author that, with the help of the gold-leaf electroscope, measurement of potential can be made of, at any rate, 1 per cent. between, say, 50 and 300 volts, the limits depending on the particular instrument. The gold-leaf electroscope possesses many advantages over the usual type of electrometer. The latter is exceedingly troublesome to set up and work, and requires very great care in maintaining satisfactory insulation. Its capacity is many times that of the electroscope, which can therefore measure much smaller currents. In addition, the electroscope is much cheaper, takes up very little space, is easily transported, and can be used in any position.

* Communicated by the Director.

[1] *Transactions of the American Electrochemical Society,* vol. 29.

The capacities of gold-leaf electroscopes of various patterns have been determined by a method which depends upon obtaining the relation between the divergence of the leaf and the potential applied to it, and the observation of the fall of potential of the leaf system when it shares its charge a convenient number of times with a standard parallel plate air condenser. It is found that the capacity is practically independent of the amount of divergence of the leaf, except when this divergence is very small, in which case the capacity becomes slightly lower. Ionization currents of the order 10^{-13} ampères can be accurately measured by an electroscope of capacity 1 cm. For some purposes the gold-leaf electroscope possesses marked advantages over the quadrant electrometer. The method employed was found to give satisfactory agreement with the results given by another method.

Delaware Water Gap Cut by Nature's Whip-saw. ANON. (*U. S. Geological Survey Press Bulletin,* No. 274, May, 1916.)—Delaware Water Gap is a vertical-walled trench, 1200 feet deep, in the narrow ridge of Kittatinny Mountain through which Delaware River flows. Did the river find this gateway ready-made through the mountain or did it cut its way through the hard mountain ledges, and if so, how could it accomplish its mighty task?

By the study of the geology of the region the following history has been worked out. After the rocks had been formed, layer by layer, as sediments in the sea they were folded and tipped on end and worn down by Nature's forces to a gentle surface across which Delaware River flowed to the sea. The top of Kittatinny Range was then part of this surface, and the adjacent area that is now lowlands stood nearly at the same level. Elevation of the land caused the Delaware and its tributaries to wear away the softer rocks and leave the harder rocks standing in relief as ridges. The hard rocks that compose Kittatinny Range formed rapids in the Delaware where it crossed them, but the river gradually cut this barrier away.

It is easy to believe that streams can remove soft shale and limestone in their course, but it may seem at first thought impossible that water alone can cut away hard rock. The water, however, is only a medium, for the cutting is done by the sand, gravel, and bowlders carried by the stream, just as emery fed to a saw cuts through the hardest rock or steel. Large, round holes that were ground into hard rocks by the churning of pebbles at the bottom of small falls have been left as "potholes" on the sides of gorges as the evidence of such stream cutting. So the Delaware, concentrating its power on a small section of the hard rock of Kittatinny Range, was able, during a long period, to cut the gap through the rocky barrier.

The story is told more fully and in plain language in the text printed on the back of the U. S. Geological Survey's Delaware Water Gap map, which is sold by the Survey for 10 cents.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, May 17, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 5.

The Chairman announced that the business of the meeting would be the annual presentation of the Institute's highest awards in recognition of distinguished scientific and technical achievements, and recognized Dr. Harry F. Keller, who gave an account of the work of Dr. Theodore William Richards, of Harvard University, recently recommended by the Institute's Committee on Science and the Arts for the Franklin Medal in recognition of his "numerous and important contributions to inorganic, physical, and theoretical chemistry, and particularly his classical series of redeterminations of the atomic weights of the more important chemical elements." Dr. Keller then read a letter from Mrs. Richards and a telegram from Dr. Richards regretting that a temporary illness prevented the latter from being present to receive the medal in person. The President announced that the medal and accompanying certificate would be forwarded to Dr. Richards.

Dr. Keller then introduced Dr. John J. Carty, chief engineer of the American Telephone and Telegraph Company, who had also been recommended for the award of the Franklin Medal in recognition of his "long-continued activities in the telephone service, his important and varied contributions to the telephone art, his work in the establishment of the principles of telephone engineering, and his signal success in directing the efforts of a large staff of engineers and scientists to the accomplishment of the telephonic transmission of speech over vast distances."

The Chairman presented the medal to Dr. Carty, who expressed his thanks for the honor conferred upon him and then read his paper on "The Telephone Art."

Dr. Keller was again recognized by the Chairman and described the work of the American Telephone and Telegraph Company, which had been recommended for the award of the Elliott Cresson Medal in recognition of its "constructive and far-seeing policy in the development of the art of telephony, in the promotion of telephone engineering, in the establishment of its telephone system in every part of the United States, and for placing all of the states of the Union in speaking communication." He introduced Mr. Theodore N. Vail, president of the company, to whom the medal was presented. Mr. Vail, in a brief address, expressed his thanks and the thanks of his associates and every individual of the Bell System for the complimentary tribute.

Dr. Hoadley was then called upon to read Dr. Richards's address on

"The Essential Attributes of the Elements," which had been prepared for the occasion.

This was followed by a demonstration of transcontinental and wireless telephony given by the American Telephone and Telegraph Company. Messages were received from and transmitted to numerous western cities, including Pittsburgh, Chicago, Denver, Omaha, Salt Lake City, Winnemucca, and San Francisco. Telephonic communications were received by wire at Arlington, Virginia, then transmitted by wireless to New York City, and from that city by wire to the audience.

Greetings were exchanged by various members of the Institute and non-resident members and others in San Francisco, and musical selections played in the latter city were heard by the entire audience, each chair being supplied with a telephone receiver.

A talking-moving picture of Mr. Thomas A. Watson, early associate of Dr. Alexander Graham Bell, describing the latter's earliest experiments with the telephone, as well as moving pictures of telephone construction and operation, were shown.

Adjourned.

R. B. OWENS,
Secretary.

Demonstrations of transcontinental telephony were repeated at 6, 7:15, and 8:30 o'clock P.M., at which Vice-president Louis E. Levy presided. Each demonstration was preceded by an explanatory address by Mr. W. F. Schmidt, of the American Telephone and Telegraph Company.

(A full account of the meeting will appear in the next issue.)

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 3, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 3, 1916.

MR. C. E. BONINE *in the Chair.*

The following report was presented for final action:

No. 2667.—Dixie Magneto. Advisory.

The following report was presented for first reading:

No. 2672.—Self-adjusting Pipe Wrench. Advisory.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, April 27, 1916, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

Mr. Walter V. Turner, assistant manager, Westinghouse Air Brake Company, Wilmerding, Pa., delivered a lecture, entitled "The Vital Relation

of Train Control to the Value of Steam and Electric Railway Properties." The lecturer, with the help of lantern slides, demonstrated that train control is as potent a factor in the producing value of a railroad as is the locomotive. The fundamental purpose of a railroad is to save time. To avoid duplicating properties, capacity is essential, and this involves high speed and great frequency of trains. Increased capacity by such means is practicable only to the degree that train control is adequate. Safety is as essential to integrity of traffic and successful operation as earning power. Consequently, the relative value of railway properties is entirely dependent upon the ability to keep trains in motion as close together as the state of the art for controlling trains will permit. Railroad capacity in cities has become an exceedingly important consideration, since the transient population during the day, because of "skyscrapers," is very great as compared with that of a few years ago. A brief illustration was given of recent development in train control equipment which has resulted in the doubling of railroad capacity.

After an interesting discussion by Messrs. Young, Gibbs, and others, a rising vote of thanks was extended to Mr. Turner.

Adjourned.

T. R. Parrish,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May 10, 1916.*)

RESIDENT.

Mr. Thomas H. Griest, civil engineer, 646 Westview Avenue, Germantown, Philadelphia, Pa.

NON-RESIDENT.

Mr. G. M. Basford, president, Locomotive Feed Water Heater Company, 30 Church Street, New York City, N. Y.

Prof. P. Dunnington, Department of Chemistry, University of Virginia, Virginia.

Mr. R. Karl Honaman, student, Franklin and Marshall College, Lancaster, Pa.

Mr. Frank A. Stanley, editor and author, 1530 West Main Street, Willimantic, Conn.

CHANGES OF ADDRESS.

Mr. Herbert S. Berliner, care of Berliner Gramophone Company, Montreal, Quebec.

Mr. Fred. Denig, 1012 Peoples Avenue, Troy, N. Y.

Mr. N. E. Funk, 5115 Regent Street, Philadelphia, Pa.

Mr. Chester Lichtenberg, 140 Glenwood Boulevard, Schenectady, N. Y.

Mr. Melvin L. Severy, The Redford, 1334 Commonwealth Avenue, Allston, Mass.

NECROLOGY.

Mr. William Stanley, Great Barrington, Mass.

LIBRARY NOTES.

PURCHASES.

ARRHENIUS, SVANTE.—Quantitative Laws in Biological Chemistry. 1915.
BECCARIA, GIAMBATISTA.—Treatise Upon Artificial Electricity. 1776.
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EIFFEL, G.—Nouvelles recherches sur la resistance de l' air. 2 volumes. 1914.
GARDNER, W. M., ed.—British Coal-tar Industry. 1915.
GOOCH, FRANK A.—Representative Procedure in Quantitative Chemical Analysis. 1916.
Municipal Year-book of the United Kingdom for 1914.
National Association of Railroad Commissioners, Proceedings, 27. 1915.
Readers' Guide to Periodical Literature, Cumulated, vol. 3. 1910–1914.
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West Virginia, Geological Survey—Lewis and Gilmer Counties. 2 volumes. 1916.
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ZENNECK, J., and SEELIG, A. E.—Wireless Telegraphy. 1915.

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Brandis & Sons Manufacturing Company, Catalogue No. 20 of Instruments of Precision. Brooklyn, N. Y., no date. (From the Company.)
Buffalo Wire Works Company, Catalogue No. 8. Buffalo, N. Y., no date, 1916. (From the Company.)
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Deming Company, Catalogue No. 25 of Deming Pumps for Hand and Power. Salem, Ohio, 1916. (From the Company.)
Denison University, Annual Catalogue, 1915–1916. Granville, Ohio, 1916. (From the University.)
Indian Railway Conference Association, Proceedings of the Locomotive and Carriage Superintendents' Committee, 1915. Moghalpura, Punjab, no date. (From the Association.)
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Iowa State College of Agriculture and Mechanic Arts, General Catalogue, 1916–1917. Ames, Iowa, no date. (From the College.)
Massachusetts Board of Education, Seventy-ninth Annual Report, 1914–1915. Boston, 1916. (From the Board.)
Mysore Government, Meteorological Department, Report on Rainfall Registration in Mysore, 1914. Bangalore, 1916. (From the Department.)

National Commercial Gas Association, Proceedings of the Eleventh Annual Convention, 1915. New York, no date. (From the Association.)
New York Central Railroad Company, Report of the Board of Directors to the Stockholders, 1915. New York, no date. (From the Company.)
New Zealand Official Year-Book, 1915. Wellington, N. Z., 1915. (From the Government Statistician.)
Oberlin College, Annual Catalogue, 1915–1916. Oberlin, Ohio, 1916. (From the College.)
Pennsylvania Board of Public Charities and Committee on Lunacy, Forty-fifth Annual Report, 1914. Harrisburg, 1915. (From the State Librarian.)
Pennsylvania Railroad Company, Sixty-ninth Annual Report, 1915. Philadelphia, 1916. (From the Company.)
Pennsylvania State Librarian, Report, 1915. Harrisburg, 1916. (From the State Librarian.)
Philadelphia Electric Company Section of The National Electric Light Association, Current News, vols. 11 and 12, 1915 and 1916. Philadelphia, 1915. (From the Company.)
Redwood Manufacturers Company, Catalogue No. 7 of Remco Redwood Pipe. San Francisco, no date. (From the Company.)
Royal Canadian Institute, Transactions, November, 1915. Toronto, no date. (From the Institute.)
Society of Naval Architects and Marine Engineers, Transactions, vol. xxiii, 1915. New York City, 1916. (From the Society.)
Sydney University Engineering Society, Journal and Abstract of Proceedings, vols. xviii and xix, 1913–1914. Sydney, no date. (From the Society.)
Taunton, Massachusetts, Water Commissioners, Fortieth Annual Report, 1915. Taunton, 1916. (From the Board.)
University of Colorado, Catalogue, 1915–1916. Boulder, 1916. (From the University.)
University of North Dakota, General Catalogue, 1915–1916. University, no date. (From the University.)
University of the State of New York, Ninety-sixth and Ninety-seventh Annual Reports of the New York State Library, 1913 and 1914. Albany, 1915 and 1916. (From the University.)
University of Vermont, Catalogue, 1915–1916. Burlington, 1916. (From the University.)
Virginia Geological Survey, Bulletin No. X, Surface Water Supply of Virginia, by G. C. Stevens. Charlottesville, 1916. (From the Survey.)
Watuppa Water Board, Forty-second Annual Report, 1915. Fall River, Mass., 1916. (From the Board.)
Wheeler, C. H., Manufacturing Company, Catalogue, Condensing Equipment. Philadelphia, 1916. (From the Company.)

BOOK NOTICES.

Elevators: A Practical Treatise on the Development and Design of Hand, Belt, Steam, and Hydraulic Elevators, by John H. Jailings. 224 pages, 5½ x 8½ inches, with index; 173 illustrations. Chicago, American Technical Society, 1915. Price, $1.50.

It is common experience that in the development of every sort of mechanical appliance no degree of technical acumen can replace the element of gradual evolution. Consequently the history of such developments in a given field is quite as important in determining a system and design to be adopted as are the fundamental principles employed in the arrangement of and determination of sizes of its component parts. The present volume is devoted to the former phase of the subject and might properly be termed an album of designs representing past and present-day successful practice in elevator driving mechanism. Every variety of platform lift, from the one-story sidewalk lift to the elaborate installations employed in high office building service, is described, along with its various controlling devices. Hydraulic elevators, a type whose value has been proved by widespread adoption for both high and low lifts, is given an adequate share of attention. A concluding chapter describes electrically driven elevators, including those equipped with push-button control for private use, and the recently developed gearless "one-to-one" type which appears to be rapidly superseding the hydraulic systems.

The discussion on the proper proportions of worm gears for the best efficiency, to which several pages are devoted, may be found at length in modern treatises on gearing. The space thus utilized might have been employed to better advantage in giving an outline of the method in current use of determining the proportions of the very long plungers used in high-lift elevators, a problem peculiar to elevator work which will probably not be found analyzed in text-books on applied mechanics. As a descriptive treatise, however, of apparatus of past and present usefulness the book is a welcome addition to the somewhat scant literature of the subject.

L. E. Picolet.

The Industrial Arts Index, which has recently completed its third year, is a cumulative index to 180 engineering and trade publications. It appears in February, April, June, October, and December of each year, and each number is fully cumulated from the beginning of the year to the date of issue.

The December number of each year is the annual volume and indexes all the articles in the publications of the year in one alphabet, under as many subject headings as may be necessary. As a guide to current literature the *Index* is extremely useful.

Requests for sample copies or information as to rates of subscription should be made to the publishers, The H. W. Wilton Company, White Plains, New York.

PUBLICATIONS RECEIVED.

Mechanical Technology, being a treatise on the materials and preparatory processes of the mechanical industries, by G. F. Charnock. 635 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, 1915. Price, $3.

Practical Physiological Chemistry, a book designed for use in courses in practical physiological chemistry in schools of medicine and of science, by Philip B. Hawk, M.S., Ph.D. Fifth edition, revised and enlarged. 638 pages, illustrations, plates, 8vo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, $2.50.

Michigan State Board of Health: Forty-second annual report of the secretary for the fiscal year ending June 30, 1914. 159 pages, 8vo. Lansing, Mich., State Printers, 1915.

U. S. Bureau of Mines: Technical Paper 126, The Casting of Clay Wares, by Taine G. McDougal. 26 pages, illustrations. Washington, Government Printing Office, 1916.

Oil Fuel, by Ernest H. Peabody. A paper presented at the International Engineering Congress, San Francisco, Cal., September, 1915, and reprinted from the *Transactions*. 134 pages, illustrations, plates, tables, 8vo.

Pennsylvania Topographic and Geologic Survey: Oil and Gas Map of Southwestern Pennsylvania. 30 × 31 inches, with descriptive pamphlet. Harrisburg. State Printer, 1916.

Athenæum Subject Index to Periodicals, 1915. Issued at the request of the Council of the Library Association. Science and Technology, with special reference to the war in its technological aspects. 79 pages, quarto. Price, 2s. 6d. Economics and Political Sciences: Law. 28 pages, quarto. Price, 1s. London, The Athenæum, 1916.

Air-friction Automobile Speedometer. ANON. (*Scientific American*, vol. cxiv, No. 16, April 15, 1916.)—Depending upon the principle of air friction and consisting essentially of two metal cups fitting one into the other, but not touching at any point, a speedometer has been developed to a commercial stage after three years' experimenting on the part of a leading watch company. The new speedometer is unique in that it does not employ the centrifugal or magnetic principle as do other types of speedometer in general use; instead, it relies on the friction of air as developed by the metal surfaces. The two main components of the speedometer in question are a driving cup, which is rotated by power from one of the automobile wheels through flexible shafting, and, suspended over and around it, a driven cup The driven cup, carrying on its periphery indicating the miles per hour attained, is inverted over and around the driving cup. This cup, as is also true of the driving cup, in reality consists of a double cup. In operation, the driven cup generates air friction which, were it not for a regulating hairspring serving normally to maintain the indicating cup at the zero marking, would cause the latter to revolve. The hairspring is so adjusted that the speed readings are proportional to the angular deflections, experiments having shown that the air friction varies directly with the speed.

CURRENT TOPICS.

Coating Metals with Zinc. ANON. (*Iron Trade Review*, vol. lviii, No. 15, April 13, 1916.)—An interesting instance of adopting a process to changed conditions is found in a new apparatus for coating metals with zinc film. The Metals Coating Company of America has developed the Schoop metal spraying process in which zinc wire or other metal wire is melted in a gas flame and projected under pressure onto the surface to be coated. Under present conditions in the metal market this wire has become exceedingly expensive. To fill the need for a less costly process, the apparatus has been modified to permit the employment of zinc in the less costly form of dust. It consists of a conical receptacle which has another similarly-shaped receptacle inside, with a small space between. Zinc dust is placed in the inner cone and compressed air is admitted through a hose at the top of the space between the two cones. A valve at the bottom of the inner compartment allows the zinc dust to be caught up by the air current and carried through a discharge tube to a spraying device. The zinc dust is there blown from an inner nozzle through an acetylene gas flame, the heat of which is sufficient to melt the zinc. In the melted condition the particles of zinc are projected at high velocity upon the surface to be coated by the action of the blast. Adjustable valves regulate the quantity of zinc dust allowed to pass into the air current and also the quantity of gas used to melt the metal.

The apparatus weighs about twenty pounds and uses air at a pressure of about five pounds per square inch. Acetylene gas, the heating agent, is easily available, and has been found to give good results with zinc dust. The present cost of zinc wire is about $1.25 per pound, while zinc dust, which is a by-product of the zinc smelter, may be obtained at about thirty cents per pound. The portability of the apparatus adds to its usefulness for work in the field in coating structural or bridge steel with a film of zinc to resist corrosion. Even at ordinary price levels the use of zinc dust is less expensive than wire, a feature which considerably broadens the application of this method of coating and makes possible its use on much larger surfaces than when zinc wire is used.

Light Transmission Through Telescopes. M. KOLLMORGEN. (*Transactions of the Illuminating Engineering Society*, vol. xi, No. 2, March 20, 1916.)—As is generally known, the amount of light energy which falls upon a glass surface is divided into two parts: a smaller one which is reflected back into the original medium, and a larger one which continues into the glass and is refracted in it and, in the telescope, forms an image. The relative amounts of these two quantities

for vertical incidence can be readily computed in terms of the refracted indices of the media beyond and before the surface of incidence. The amount of light transmitted through each element of an optical instrument may be between 85 and 95 per cent. of the available total. Hence the efficiency in an optical instrument having a considerable number of elements, measured by the continued product of the efficiency of each component, may be objectionally low. For example, in a modern periscope gun-sight the efficiency of light transmission is 36.2 per cent., and this figure is reduced to 32.5 per cent. by absorption of the combined thickness of prisms and lenses. In some modern periscopes for submarines barely 20 per cent. of the available light reaches the observer.

It would thus be a desirable thing if it were possible to treat the glass surfaces in such a way as to reduce reflection. It has been known for some time that it is possible to increase the reflecting power of a surface. Professor Wood, of Johns Hopkins University, some years ago made the remarkable discovery that by coating a glass surface with a thin solution of collodion a degree of reflection could be obtained quite out of proportion to the refractive indices of either the glass or the collodion itself. For optical work, however, just the opposite is desired, and, as very often is the case, chance has given us a hint which has already produced very desirable results. In 1904, H. Dennis Taylor, the well-known English lens expert and designer of the Cook lens, saw a very badly-oxidized photographic lens which had been returned to be repolished . Possibly just to find how much light was lost through this oxidation, he exposed two plates under identical conditions, one through a perfectly new, untarnished lens, the other the badly-oxidized specimen. To his great surprise he found that the plate taken with the badly-tarnished lens had received considerably more light than that taken with the new lens, and, acting upon this hint he sought means of oxidizing lenses artificially. He soon found chemicals that would attack at least some of the glasses used in optical instruments. His treatment consists in immersing the lens immediately after polishing for a short time in an aqueous solution of ammonia and hydrogen sulphide. Experimenting further along the same lines, the writer has found means of oxidizing most of the glasses used in optical work. Using a barium crown glass of refractive index of about 1.6, the untreated glass, in agreement with the Fresnal formula and with photometric measurement, transmitted 89 per cent. of the light, while of a set of similar treated samples the best transmitted 96 per cent. When a number of these are mounted in series, the difference in reflecting power is easily observed by the unaided eye, but the photometer shows that the amount of light taken away from the reflected part is actually not absorbed by the roughness of the surface, but is added to the transmitted part.

Oxy-acetylene Welding in Heavy Sections. C. K. BRYCE. (*Steel-Iron,* April, 1916.)—Fusion welding by the oxy-acetylene process in both cast iron and steel of heavy sections is meeting with greater favor as the engineering and mechanical fields gain more confidence in the process and grow to appreciate its merits and limitations. The process has been established for a sufficient length of time to point out the fundamental methods of procedure. As the subject is more carefully studied, various experiments and changes will be introduced which will add greatly to the quality and economy of the process. In the present stage of the process experience has shown certain limitations.

In steel welding, where the section welded is submitted to strain, the greatest success has been attained in sections under six inches if square and five inches if round. In plate work, metal 1 1/4 to 1 1/2 inches in thickness has been welded satisfactorily. In cast iron the size of the section is limited only by the amount of pre-heating that can be given it and effect the resulting expansion. Sections as heavy as 12, 14, and 16 inches have been welded successfully. All heavy work should be pre-heated. In cast iron this is necessary in order to eliminate chance of failure through contraction and expansion strains. While the chance of failure in steel is not as great because of this, nevertheless the internal strains in the weld will be reduced by the procedure. In additon to offsetting the mechanical difficulties, pre-heating should be used to introduce a certain quantity of heat into the metal that would otherwise be supplied by the blowpipe, thus considerably reducing the cost of the operation.

Beams Without Lateral Support. R. FLEMING. (*Engineering News,* vol. 75, No. 14, April 6, 1916.)—The percentage most widely adopted of tabular safe loads for beams supported sidewise to be used for beams not so supported are those given in the Pencoyd book, "Steel in Construction," 1884, edited by James Christie. As long as it was published the Pencoyd book retained the table of these values. The table will be found in editions of the Carnegie "Pocket Companion" for 20 years previous to 1913. It is still in the handbooks of the Bethlehem Steel Company, The Jones & Loughlin Steel Company, and the Phœnix Iron Company. It is also in Kent and Kidder and quoted by many writers. To many who have accepted these values as the result of precise investigation, Mr. Christie's views on the subject 25 years after they were first published will be a surprise.

"Some experiments were made on beams of considerable length in proportion to cross-section and without lateral support, the object being to ascertain approximately how the working loads should decrease as the length of the beam increased. As I remember it, the results of these experiments were unsatisfactory, and, although tables were formulated suggesting a scale of reduction for loads on

long beams without lateral support, yet these tables had neither a rational nor an experimental basis, but were derived by a general estimate of probabilities. For long beams, when the beam is reasonably straight and its load free from vibration, a large load appeared to be safely borne. But this was not the case when lateral vibrations were set up. The long beam heavily loaded appeared to be in a state of unstable equilibrium."

Subsequent investigation does not appear to have placed these load-reduction factors on a more rational basis. The writer suggests the formula $19000-250\ l/_b$ (l = unsupported length; b = width of compression flange) for the unit stress, to be used when the lateral unsupported length exceeds 12 times the width of the compression flange. The length should in no case exceed 50 times the width of the compression flange.

Bahia's Trade in Diamonds and Carbonados. R. FRAZER, JR. (*U. S. Commerce Report,* No. 41, February 18, 1916.)—There is a considerable business done at Bahia (Brazil) in both rough diamonds and carbonados (miner's diamonds), but exact figures cannot be given as to the volume of the trade. That it is of some importance, however, is evident from the fact that 11,803 carats of rough diamonds and 3714 carats of carbonados were invoiced at the Bahia consulate for shipment to the United States alone in 1915. It is interesting to note that the state of Bahia is the only part of the world in which high-grade carbonados are found. The mining of precious and semi-precious stones is carried on here chiefly by individuals, or at least by small-scale enterprises, and not by large companies that both mine and export their own product. The stones, therefore, arrive at Bahia, the centre of the trade, singly or in small lots, and are there bought up by middlemen and exporters.

The stones most difficult to obtain in any quantity are, of course, those larger than ¾ to 1 carat, but stones of the former weight and mêlés of ½ carat or less are comparatively plentiful. Various lots of rough diamonds and carbonados of mixed sizes have lately been invoiced at this consulate at prices ranging from $9 to $30 and $15 to $36 per carat respectively, while the average prices for the year 1915, as declared at this consulate, were $18 per carat for diamonds and $32 for carbonados. The average value of the diamonds exported was, therefore, less per carat than the carbonados. At present, mêlès of ½-carat stones or smaller should be obtainable at about $10 per carat; ¼-carat stones, $12 to $14; ½-carat, $16 to $20; ¾-carat, $20 to $23; 1-carat, $25, and from 2 carats upward, $35. It is believed that these prices may be taken as approximately average ones, although it is impossible to give exact figures with respect to articles which vary so greatly in value with small differences in quality.

Bort is not plentiful at Bahia, and very little is dealt in, it being said that the prices asked for it are higher than for bort from other origins.

A Method for the Determination of Free Caustic Alkali in Soap. F. H. NEWINGTON. (*Journal of the Society of Chemical Industry,* vol. xxxv, No. 2, January 31, 1916.)—It is well known that the addition of common salt to an aqueous solution of soap "salts out" or completely separates the soap. This separation of soap can be effected equally well by means of sodium sulphate, and any free caustic alkali in the sample is separated by the aqueous sodium sulphate solution. The caustic alkali thus extracted is free from soap, and may be readily determined by titrating with N/10 sulphuric acid, using silver nitrate as a spot indicator. The advantage of using sodium sulphate to "salt out" the soap is that by this means a solution is obtained which will not produce an insoluble compound with the silver nitrate used as an indicator in the titration. If sodium chloride were used to salt out the soap, the solution obtained would, of course, form the insoluble chloride with the silver nitrate and hence leave no soluble silver salt to react with the hydroxide. A 5 per cent. solution of silver nitrate is sufficiently strong to precipitate any small amount of chloride that may be dissolved from the soap, and still to leave an excess of silver nitrate to react with the hydroxide. This method has been found quite satisfactory in testing toilet, household, and soft soaps, as well as soft soap substitutes.

Radium, Uranium, and Vanadium in 1915. ANON. (*U. S. Geological Survey Press Bulletin,* No. 256, January, 1916.)—Radium, uranium, and vanadium are closely connected in occurrence in the principal fields, Colorado and Utah, but in 1915, although the European war caused a great slump in the production of ores of radium and uranium, it caused a considerable increase in the production of ores of vanadium.

According to reports for 1915 received by the United States Geological Survey and compiled by Frank L. Hess, the output was 23.4 tons of uranium oxide and 6 grammes of radium contained in the carnotite ores produced, and 635 tons of vanadium contained in the carnotite ores shipped and in the chemical concentrates from the roscoelite ores. In 1914 the ores produced contained 87.2 tons uranium oxide, 22.3 grammes radium, and 435 tons vanadium.

The United States has much the largest known radium-bearing deposits of the world, but the market for radium is mostly in Europe, for, though Americans like to feel that they are sufficiently progressive to take hold of and use to the full new discoveries, inventions, and processes, yet the European municipalities and hospitals have been buying and utilizing most of the radium produced. When the war began, therefore, causing European money to flow into other channels, the demand for radium fell off so greatly that there was practically no market for radium or uranium ores in the early part of 1915, and very little market during any part of the year. Mining of carnotite ores, except by the National Radium Institute (Inc.) under the

supervision of, and in coöperation with, the Bureau of Mines, and except for such work as was necessary for assessment work to hold claims, was nearly stopped.

The Institute mined nearly the 1000 tons of ore contracted for from the Crucible Steel Mining and Milling Company's claims in Long Park, Montrose County, Colo., and obtained 70 tons of concentrates, carrying about 3 per cent. of uranium oxide, by concentrating material carrying 0.7 per cent., which had been thrown on the dumps. The Institute fully accomplished its purpose to work out a practical process of producing radium at a cost much below the market price of the element and crystallized out radium salts containing 6 grammes of the element. It delivered during the year 3.006 grammes of radium (element) at a cost of $37,599 per gramme. Near the close of the year 1.1 grammes of radium (element) was contracted for by a private company for $132,000, or $120,000 a gramme. This comparison shows the great success of the work of the Bureau of Mines. Its ore concentration method seems to have also been highly successful. After mining its quota of ore from the Crucible Steel Mining and Milling Company's property, the Institute came into the market as a purchaser of ore.

In the later half of the year Dr. W. A. Schlesinger and associates established a radium reduction plant in Denver. They acquired an interest in the Copper Prince claims, from which ore was mined, and bought a further quantity. Ore carrying about 5000 pounds of uranium oxide, containing about 640 milligrammes of radium, was treated during the year.

The Carnotite Reduction Company, made up of Dr. H. N. McCoy, of the University of Chicago, and associates, purchased from Galloway and Belisle a quantity of ore which had been stored in Placerville, Colo., and the radium will be extracted in Chicago. The company will mine ore from claims it has bought.

The Standard Chemical Company did no work on its claims except that required by law, but in this work produced and shipped a quantity of ore from its properties in Colorado and Utah, and purchased, it is stated, a considerable number of claims. It was reported in December that the company had produced a total of 14 grammes of radium (elemental) and that its ore had averaged 1.7 per cent. uranium oxide. Probably between 4 and 5 grammes of this quantity was produced during 1915.

The production of radium salts in this country during the year was probably nearly 11 grammes.

Only a small quantity of ore is thought to have been shipped to Europe during the year. J. S. McArthur & Co. shipped one lot of ore from its claims near Greenriver, Utah, to Glasgow, Scotland.

Peptone as an Addition Agent in Stannous Ammonium Oxalate Baths. F. C. MATHERS and B. W. COCKRUM. (*Proceedings of the American Electrochemical Society*, April 27–29, 1916.)—

Tests of tin-plating baths by these investigators indicated that the best tin deposit is obtained from a sannous ammonium oxalate bath containing peptone as an addition agent. Without the peptone the deposit is of no value as a protecting coat, because it consists of projecting needle-like crystals. The effect of the peptone is very remarkable. As soon as it was added, the tendency to form the projecting, loosely-adhering crystals ceased and the deposits became so smooth and finely crystalline that thick cathodes (0.5 to 1 cm. thick) could be prepared, and so firm and coherent that shavings could be cut from the deposit with a knife. Clove oil, glue, gelatine, and formin, agents which have been found effective with other metals, were practically without any beneficial influence in preventing the formation of crystals. Carbon disulphide, even in small amounts, made the deposit spongy and non-adherent, a condition which persisted until the carbon disulphide was exhausted, when the deposit again became crystalline.

The addition of peptone to the stannous ammonium oxalate bath is essential for the production of a thick, smooth, finely crystalline deposit of tin. No other tin bath (except possibly the sulphide, which was not tried) is known from which such a thick, smooth deposit can be obtained. A good composition of bath is : 5 per cent. stannous oxalate, 6 per cent. ammonium oxalate, 1.5 per cent. oxalic acid, and 0.25 per cent. peptone. The stannous oxalate may be easily made by precipitating a solution of stannous chloride with oxalic acid. The bath was run at room temperature at 0.4 ampère per square decimetre (3.6 per square foot). The solution must be stirred at intervals.

Wireless Achievements at Tufts College. ANON. (*The Electrical Review and Western Electrician,* vol. 68, No. 16, April 15, 1916.)—The transmission of music by wireless with a small amount of power, giving a range of more than 100 miles, so that ships at sea have picked up tunes, has been brought about at the station of the American Radio & Research Corporation at Tufts College, Massachusetts, of which Harold J. Power is general manager. The mere fact of sending music to the distance mentioned is not of itself a remarkable feat, but by means of a novel method of introducing the sounds in the radiated waves, resulting in articulation and loudness in the waves received, a marked gain has been achieved.

To provide the high-frequency current necessary, Professor Power employed an oscillon bulb, the invention of Lee de Forest, of New York. It is recognized that there are two important factors in the successful transmission of wireless telephone messages. One is the generating of high-frequency currents, and the other is the modulation in accordance with the voice or the music to be transmitted. It is the latter of these two problems that Professor Power is especially interested in, because the De Forest oscillon is recognized as a perfect means of generating the needed high-frequency current. It has been possible for some time to obtain sufficient power to

transmit telephone messages to any distance, but how to introduce the voice in high-power stations in a practical manner is the great problem of radio telephony, and to this branch of work Professor Power is now devoting much attention. His device for introducing the voice is far from perfected as yet, but, from reports thus far received, successful results have been obtained. Operators at several stations on Cape Cod have reported recording the strain of well-known popular airs produced by a phonograph, and, in some instances, steamers entering Boston reported picking up the music more than 100 miles out from port.

The radio station is one of the most complete in the country. Students at Tufts College have the facilities at their disposal for experimental work, though the plant is owned by a private corporation, and a number of valuable results have been developed by numbers of the Tufts Wireless Club.

Land Drainage by Means of Pumps. S. M. WOODWARD. (United States Department of Agriculture, Bulletin No. 304, November 19, 1915.)—The drainage of low-lying lands by the use of pumping machinery to lift the drainage water over levees into adjacent streams or other drainage channels is a recent development in this country. Along the banks of our larger interior rivers considerable areas of bottom land are subject to overflow from the adjacent streams during the high water occurring usually with great regularity throughout the spring and early summer months. Such lands in their native state do not become dry enough to be subjected to ordinary cultural operations until well toward the middle of the summer, and hence can not be used for growing ordinary crops. In this natural condition they are therefore good for nothing but pasture, and have accordingly but little agricultural value.

So long as there exists in a locality any unoccupied or unutilized higher land suitable for agriculture there is little demand for the use of lands lying so low as to require the use of pumps. But the present high price of agricultural land justifies a heavy expenditure for the conversion to a productive state of areas formerly considered almost valueless, especially in those regions where agricultural land values are particularly high, either on account of unusually favorable natural conditions or the proximity of large centres of population.

Drainage by means of pumps has been carried on in European countries for the last 100 years, and has been rapidly increasing in this country during the last 25 years. Through this extensive experience, including numerous failures, a considerable amount of knowledge is now available on the subject of the proper arrangement and the requisite capacity of pumping plants. Notable examples of successful work of this character are found in Holland, eastern England, and in Ireland, while large marsh areas in both northern and southern Italy depend upon pumps for adequate drainage. The pumps which were first used were the well-known scoop wheel and

Archimedean screws which were driven by windmills. In modern installations, however, the pumps are invariably of the centrifugal type, driven by a steam, gas, or electric motor.

Performance of 30,000-Kw. Steam Turbo-generators. ANON. (*Electrical World,* vol. 67, No. 20, May 13, 1916.)—The extent to which the steam turbine has displaced the piston engine in large units is strikingly shown by the performance of the 30,000-Kw. units recently installed in the Seventy-second Street Station of the Interborough Rapid Transit Company of New York. In 1900 this station housed eight Reynolds Allis-Chalmers steam engines of a double combination horizontal-vertical cross-compound design. Each unit was rated at 5000 Kw., with a maximum rating of 7500 Kw. In a space no greater than taken by one of these units a 30,000-Kw. turbine unit now stands, operated from the same boilers now equipped with underfeed stokers, and superheaters to give 200 degrees of superheat when the boilers are delivering three times their rated output. The boiler pressure is 205 pounds per square inch gauge. The steam engines operated originally at 175 pounds gauge and no superheat. The cost of the engines, generators, and condensers was $40 per kilowatt, while the cost of the new turbine and condensers is $9 per kilowatt. The steam engine water rate was 17 pounds per kilowatt-hour, as compared with about 11.4 for the turbines operating under similar load conditions.

The performance of the unit in outclassing in operating efficiency, cost, space requirements, and ability to handle swinging loads amply establishes the enviable position of the steam turbine as a prime mover. The old engines, which at the time of their installation represented the last word in engine design, found no purchaser but the junk dealer. It is also interesting to note that, although it was decided two years ago to use this new type of turbine, changes in the art and operation in the interim have been such that the company will now install a 70,000-Kw. cross-compound unit with three generators, any one of which may be operated independently if desired. Thus this art of generating electricity in steam-turbine driven stations has advanced to a point where, up to load factors of approximately 60 per cent., a kilowatt-hour of electrical energy can be manufactured more cheaply by this means than by water power.

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THE FRANKLIN INSTITUTE

ANNOUNCEMENTS

MEETINGS

COMMITTEE ON SCIENCE AND THE ARTS. First Wednesday of each month, 8 P.M. (except July and August).

BOARD OF MANAGERS. Second Wednesday of each month, 3.30 P.M.

INSTITUTE. Third Wednesday of each month (except June, July, August and September), 8 P.M.

SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

CHANGES OF ADDRESS

Members are particularly requested to inform the Secretary of changes of address.

OFFICERS FOR 1916

The Board of Trustees was formed in accordance with the following By-Laws passed in the year 1887:

> All Real and Personal Estate of the Institute which may hereafter be acquired by voluntary subscription or devise, bequest, donation, or in any way other than through its own earnings or by investment of its own funds, saving where the donors shall expressly provide to the contrary, shall be taken as acquired upon the condition that the same shall be vested in a Board of Trustees, who shall be appointed in the manner hereinafter indicated. Unless the title to such property shall be directly vested in said Board of Trustees by the donors, the Institute, by deed attested by the President and Secretary, which they are hereby authorized to execute and deliver, shall forthwith convey the same to said Trustees, who shall hold it in trust for the purposes specifically designated by the donors; or, if there shall be no specific designation, for the benefit of the Institute in the way and manner hereinafter provided, so that the same shall not, in any event, be liable for the debts of the Institute.

This method of separating the *body holding* the principal of the various funds from the Board of Managers, the *spending body*, is an original idea of The Franklin Institute and it is hoped it will appeal to friends who may desire to create funds to further the objects of the Institute, and the various branches of science in which they may be interested.

MEMBERSHIP.

Terms and Privileges.

THE MEMBERSHIP OF THE INSTITUTE is divided into the following classes, viz.: *Resident Members, Stockholders, Life Members, Permanent Members, Non-resident and Associate Members.*

Any one interested in the purposes and objects of The Institute and expressing a willingness to further the same may become a member when proposed by a member in good standing and elected by the Board of Managers.

TERMS.—Resident members pay Fifteen Dollars each year. The payment of Two Hundred Dollars in any one year secures Life Membership, with exemption from annual dues.

STOCK.—Second-class stockholders pay an annual tax of Twelve Dollars per share, and the holder of one share is entitled by such payment to the privileges of membership.

PRIVILEGES.—Each contributing member (including non-residents) and adult holder of second-class stock is entitled to participate in the meetings of The Institute, to use the Library and Reading Room, to vote at the Annual Election for officers, to receive tickets to the lectures for himself and friend, to attend the Section meetings and to receive one copy of the Journal *free* of charge, except associate members, who may not take part in elections.

PERMANENT MEMBERS.—The Board of Managers may grant to any one who shall in any one year contribute to The Institute the sum of One Thousand Dollars a permanent membership, transferable by will or otherwise.

NON-RESIDENT MEMBERS.—Newly elected members residing permanently at a distance of twenty-five miles or more from Philadelphia may be enrolled as Non-resident Members, and are required to pay an entrance fee ot Five Dollars, and Five Dollars annually. Non-resident Life Membership, $75.00.

Contributing members, if eligible, under the non-resident clause, on making request therefor, may be transferred to the non-resident class by vote of the Board of Managers, and are required to pay Five Dollars annually.

ASSOCIATE MEMBERS.—Associate members are accorded all the privileges of The Institute, except the right to vote or hold office, upon the payment of annual dues of Five Dollars. This class of membership is limited to persons between the ages of seventeen and twenty-five years. Upon reaching the age limit they become eligible to the other classes of membership.

RESIGNATIONS *must be made in writing, and dues must be paid to the date of resignation.*

For further information and membership application blanks address the Secretary of The Institute.

THE FRANKLIN INSTITUTE AWARDS

The following awards are made by, or on the recommendation of
The Franklin Institute
acting through its Committee on Science and the Arts:

THE FRANKLIN MEDAL
THE ELLIOTT CRESSON MEDAL
THE HOWARD N. POTTS MEDAL
THE JOHN SCOTT LEGACY MEDAL AND PREMIUM
THE EDWARD LONGSTRETH MEDAL OF MERIT
THE CERTIFICATE OF MERIT

The Franklin Medal

(Gold Medal and Diploma).—This Medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal

(Gold Medal and Diploma).—This Medal is awarded for discovery or original research, adding to the sum of human knowledge irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship. (See page xv.)

The Howard N. Potts Medal

(Gold Medal and Diploma).—This Medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products utilizing important principles or of superior excellence; and for papers of especial merit that have been presented to The Institute and published in its Journal.

The Edward Longstreth Medal of Merit

(Silver Medal and Diploma).—This Medal, with a money premium when the accumulated interest of the Fund permits, may be awarded for meritorious work in science or the arts; including papers relating to such subjects originally read before The Institute, and papers presented to The Institute and published in its Journal.

The Certificate of Merit

A certificate of merit is awarded to persons adjudged worthy thereof for their inventions, discoveries or productions.

The John Scott Legacy Medal and Premium

Is awarded by the Board of Directors of City Trusts of the City of Philadelphia, on the recommendation of The Franklin Institute. (For conditions see page xvi.)

The Boyden Premium.

Is to be awarded by The Franklin Institute under conditions detailed on page xvii.

Further information regarding the above awards may be obtained by addressing the Secretary of The Institute.

THE FRANKLIN INSTITUTE AWARDS

THE ELLIOTT CRESSON MEDAL

THE FRANKLIN INSTITUTE awards the ELLIOTT CRESSON GOLD MEDAL under the provisions of the Deed of Trust from ELLIOTT CRESSON of the City of Philadelphia, dated the Eighteenth day of February, 1848, on the recommendation of its Committee on Science and the Arts.

"This Medal and Diploma shall be awarded for discovery or original investigation, adding to the sum of human knowledge irrespective of commercial value; leading and practical utilization of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship."

For further information address the Secretary of THE INSTITUTE.

THE FRANKLIN INSTITUTE AWARDS

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM

THE City of Philadelphia holds in trust under the legacy of John Scott, of Edinburgh, a sum of money the interest of which is to be used for the encouragement of "ingenious men and women who make useful inventions." **The legacy provides for the distribution of a Medal, inscribed "To the Most Deserving," and Money Premium in the sum of $20 to such persons whose inventions shall merit the same.** The examination of the inventions submitted for the Medal and Premium has been delegated by the Board of Directors of City Trusts, of the City of Philadelphia, to The Franklin Institute, and The Institute, under the competent assistance of its Committee on Science and the Arts, undertakes to make investigations free of charge and to recommend for the award all meritorious inventions.

Applications should be addressed to the Secretary of The Franklin Institute, from whom all information relative thereto may be obtained.

Pursuant to the regulations for the award of the John Scott Legacy Medal and Premium, The Franklin Institute, of the State of Pennsylvania, has under consideration favorable reports upon the applications advertised in this Journal. Any objection to the proposed awards, based on evidence of lack of originality or merit of the invention, should be communicated to the Secretary of The Institute within three months of the date of notice.

THE FRANKLIN INSTITUTE AWARDS

THE BOYDEN PREMIUM

URIAH A. BOYDEN, ESQ., of Boston, Mass., has deposited with THE FRANKLIN INSTITUTE the sum of one thousand dollars, to be awarded as a premium to

"Any resident of North America who shall determine by experiment whether all rays of light,* and other physical rays, are or are not transmitted with the same velocity." :: :: :: ::

The following conditions have been established for the award of this Premium:

1. Any resident of North America, or of the West India Islands, may be a competitor for the Premium; the southern boundary of Mexico being considered as the southern limit of North America.

2. Each competitor must transmit to the Secretary of THE FRANKLIN INSTITUTE a memoir describing in detail the apparatus, the mode of experimenting and the results; and all memoirs received by him after the first day of January, one thousand nine hundred and sixteen, will, as soon as possible after this date, be transmitted to the Committee of Judges.

3. The Board of Managers of THE FRANKLIN INSTITUTE shall, before the first day of January, one thousand nine hundred and seventeen, select three citizens of the United States of competent scientific ability, to whom the memoir shall be referred; and the said Judges shall examine the memoirs and report to THE FRANKLIN INSTITUTE whether, in their opinion, any, and, if so, which of the memoirs is worthy of the Premium. And, on their report, THE FRANKLIN INSTITUTE shall decide whether the Premium shall be awarded as recommended by the Judges.

4. Every memoir shall be anonymous, but shall contain some motto or sign by which it can be recognized and designated, and shall be accompanied by a sealed envelope, endorsed on the outside with some motto or sign, and containing the name and address of the author of the memoir. It shall be the duty of the Secretary of THE FRANKLIN INSTITUTE to keep these envelopes securely and unopened until the Judges shall have finished their examination; when, should the Judges be of opinion that any one of the memoirs is worthy of the Premium, the corresponding envelope shall be opened, and the name of the author communicated to THE INSTITUTE. The sealed envelopes accompanying unsuccessful memoirs will be destroyed unopened, in the presence of the Board of Managers.

5. Should the Judges think proper, they may require the experiments described in any of the memoirs to be repeated in their presence.

6. The memoirs presented for the Premium shall become the property of THE FRANKLIN INSTITUTE, and shall be published as it may direct.

The problem has been more specifically defined by the Board of Managers, as follows:—

"Whether or not all rays in the spectrum known at the time the offer was made, namely, March 23, 1859, and comprised between the lowest frequency known thermal rays in the infra-red, and the highest frequency known rays in the ultra-violet, which in the opinion of the Committee lie between the approximate frequencies of 2×10^{14} double vibrations per second in the infra-red and 8×10^{14} in the ultra-violet, travel through free space with the same velocity."

*An award, made during the year 1907, covered the solution of the problem so far as the transmission of the visible and ultra-violet rays is concerned. It has been directed by the Board of Managers that the balance of the fund be retained, to be awarded to such person as shall demonstrate whether or not the infra-red rays are or are not transmitted with the same velocity as the other rays.

THE FRANKLIN INSTITUTE AWARDS

JOURNAL CONTRIBUTIONS

By a resolution of the Committee on Science and the Arts, made October 5, 1910, all papers published in the Journal of The Franklin Institute will be subject to the award of one of the following Medals—

The Howard N. Potts
Gold Medal

The Edward Longstreth
Silver Medal

The merits of the several papers appearing in the Journal during any current year will be passed upon by a Special Committee appointed for the purpose.

R. B. OWENS,
Secretary